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THE OZONIZATION OF WATER.

BY GEORGE A. SOPER, PH.D., ENGINEER AND CHEMIST, NEW YORK CITY.

[*Read February 14, 1900.*]

Among the interesting new processes for the purification of water and sewage which have appeared in the last ten years, the latest to attract public attention is the ozone treatment. As is not unusual with new inventions, large claims have been made for the ozone process, some of which will probably never be realized; but in view of the increasing interest which water-works people are showing in the subject, and the possibilities which are apparent in it, it may not be unprofitable for us to review briefly the principal facts upon which current arguments in favor of ozonization are based.

At the outset it should be stated that the theory of ozonization is extremely simple. It consists in bringing about a thorough mixture of the water to be purified and a quantity of atmospheric air which has been ozonized. When the ozone, which is a very active condition of oxygen, is brought into contact with the water, some of the organic impurities of the latter are oxidized. Oxidation, it will be remembered, is, in chemical parlance, combustion, and the effect of the ozone treatment is to destroy or burn up the objectionable matters.

It is customary to convert the oxygen of the air into ozone by means of electricity and to apply it by what might be considered a very thorough system of aëration.

The idea of purifying water by ozone appears to have had its beginning with Frölich, an engineer of the firm of Siemens & Halske, of Berlin. He was engaged in experimenting with ozo-

nizers in the hope of producing an apparatus which would yield a larger quantity of ozone for a given volume of the oxygen supplied to it than had been found possible up to that time.

Frölich's efforts to increase the efficiency of his ozonizers do not seem to have been particularly successful, but in papers published by him in 1891, upon the subject of his experiments, he makes some interesting suggestions of a new use to which the mixture of ozone and air obtained from his apparatus may be put.

He states that when impure water is treated with ozone, its quality is greatly improved. The dissolved ammonia is partly converted into nitrates, iron, when present, is precipitated in the form of hydrate, and the water is sterilized.

Frölich was not a biologist or chemist, and beyond pronouncing his opinion of the germicidal action of ozone and its power to mineralize organic impurities in water, he made no attempt to establish the usefulness of the process he proposed.

The publication of Frölich's papers was, however, soon followed by an investigation into the power of ozone to sterilize water, which was authoritative. The research was undertaken for the Imperial Board of Health of Germany, by Ohlmüller, at Berlin. Various waters were used, and the action of ozone toward many species of bacteria was carefully studied. Ohlmüller, working with a small experimental plant, found that sterilization was easily effected in distilled water to which bacteria were added. In two minutes he killed 12 247 000 typhoid bacilli and 2 791 000 cholera germs. Sewage was difficult to treat successfully, and it was not considered feasible to sterilize water which contained much organic matter in suspension.

The first attempt to work out the practical conditions under which ozone could be applied to the sterilization of large volumes of water was made by Baron Henry Tindal, of Amsterdam, who built a sterilizing plant with a capacity of 7 500 gallons per day, at Oudshoorn, near Leyden, Holland, in 1895.

The water treated was taken from the Old Rhine. It was polluted with the wastes of factories and towns and the drainage of farm lands. It was highly colored and had an unpleasant odor. There was no difficulty, however, in sterilizing the water after filtration. Very careful studies were made of the species of bacteria found in the raw water, and in some of the tests particular species were sown in order to observe the effect of ozone upon them. It was found

that the most resistant bacteria could be destroyed under conditions which promised industrial success.

The appearance of the Old Rhine water was much improved by ozonization, the color and odor being reduced, and the chemical qualities as indicated by the permanganate figure were improved fifty per cent. Finally, the water after treatment by ozone contained no substances prejudicial to health. It was free from taste and was pronounced to be in all respects excellent for drinking purposes.

Our information concerning the results of the test at Oudshoorn is taken from an official report made by Dr. Van Ermengem of the University of Ghent, who investigated the plant as an expert for the Belgian Government.

At first the ozone was generated by a Siemens apparatus similar to that which had been employed by Frölich and Ohlmüller. It consisted of two large concentric glass tubes so arranged as to leave an annular space between them through which a stream of air could be made to pass. The inner tube was filled with acidulated water and the apparatus was immersed in a bath of the same liquid. On connecting the water in the inner tube with one pole of a powerful induction coil and the water outside of the larger tube with the other pole of the coil, a current of electricity was established through the air in the annular space.

The nature of the current produced in an air-gap under such circumstances is known as the silent or brush discharge. Under properly regulated conditions there is no sparking, but a violet-colored flame which has the peculiar power of converting oxygen into ozone when the former is brought into contact with it.

In Ohlmüller's hands the Siemens apparatus yielded $\frac{1}{2}$ cubic foot per minute of ozonized air, which contained approximately four per cent. of its weight of ozone. It was supposed that increased voltages would produce increased yields of ozone, but it was found at Oudshoorn that electric potentials above 4 000 volts endangered the glass walls of the Siemens apparatus. To avoid this difficulty, celluloid was substituted for glass, and finally the use of dielectrics was discarded altogether for a new form of ozonizer which was invented by Schneller, an electrician connected with the test. This point is particularly noticed here for the reason that an important step was taken in the development of ozonizers when the old forms requiring the use of delicate dielectrics were abandoned. The new apparatus,

if not more efficient, was more durable in character and better suited to the uses of water works than the old types.

The new ozonizers used currents which were transformed to 50 000 volts. The air which was to be ozonized was filtered, dried and chilled. The improved apparatus for converting the oxygen will be described presently. Sterilization was effected by applying the ozone to the water by bubbling and by spraying. It was found that spraying gave a more intimate contact, but that the contact by bubbling could be continued longer.

At the Hygienic Exhibition held at Paris in 1896, an experimental ozone installation was made by Baron Tindal to treat the water of the Seine. The leading features of the plant resembled those at Oudshoorn, the same type of apparatus being employed. Electric power was taken from the general electric light circuit of the exhibition to operate a small dynamo whose current was transformed for use to 50 000 volts.

The ozonizers were of the sort that had been invented at Oudshoorn. They consisted of five glass-lined rectangular boxes 10 x 14 x 23 inches. Suspended from the cover of each were packages of platinum foil sheets whose edges were separated from the walls of the boxes by a space of about $\frac{3}{16}$ inch. On the glass walls opposite the platinum sheets were fastened thin gold plates. The gold was grounded and the platinum was connected with the electric transformers through glycerine resistance cells placed above the boxes. Air passed through the boxes and became ozonized by contact with the electric flames which played between the platinum and gold.

The sterilizing apparatus consisted of upright columns through which the water and ozone were pumped, passing from the bottom upward. The water and air escaped at the top. Most of the ozone was absorbed. The plant had a designed capacity of about 30 000 gallons per 24 hours when treating filtered water from the Seine which contained two parts of organic matter per 100 000.

Drs. J. Repin and Marmier of the Pasteur Institute, both of whom examined the sterilizing capacity of the plant, pronounced the Oudshoorn results fully sustained, but the bacteriological data which these gentlemen collected have never been published. The chemical effects were, as reported by Repin, — chlorine not changed, nitrates reduced slightly, partial precipitation of the carbonates of lime and magnesia and sulphate of lime. Color, odor, and taste were improved.

Regarding the cost of ozonization, it was considered that where water does not contain more organic matter than is represented by 0.4 part permanganate per 100 000, about 1 500 gallons of water can be purified with an expenditure of energy equivalent to 1 H. P.

At the Brussels Exhibition of 1897, a third trial plant for the ozonization of water was erected by Baron Tindal, with a capacity of about 100 000 gallons a day. With this plant, water from the infiltration galleries of Brussels was readily sterilized, as were samples taken from polluted canals near the coast; the latter, however, being first filtered to remove suspended solids. The essential features of the plant were similar to those at Oudshoorn and Paris. A report to the Government was made upon the efficiency of the Brussels plant by Dr. Marmier, who, it will be remembered, was mentioned in connection with the Oudshoorn test, and Prof. Leon Gerard of the University of Brussels.

Not the least important of the effects developed at Brussels are the data which relate to the cost of producing the ozone and the quantity which was required to sterilize the water. As the result of careful experiments it was announced that the concentration of ozone from the ozonizers was 4.5 mgs. per liter of air, which is about one third of one per cent. by weight. It was found that about three grams of ozone could be made with 1 H. P., that this amount of ozone would purify about 22 000 gallons of water when the organic matter did not exceed 10 parts per 100 000, and that the cost per 1 000 000 gallons was about nine dollars.

There are at present two municipal ozonization plants in Europe, both of which I have seen in operation. The first was built in 1898 at Blankenberg on the Belgian coast, to sterilize 500 000 gallons per day of canal water. As in the experimental trials already referred to, the water is filtered before treatment with ozone.

There are no special features of interest in the electrical apparatus for producing ozone at Blankenberg, except that for the glass boxes with metallic electrodes there are substituted covered troughs of metal in which there are suspended a number of platinum combs. The electric discharge takes place between the points of the combs and the adjacent walls of the troughs.

The sterilizers are three in number. They are situated in a pump house adjoining the filters, and occupy a small space near the electric machinery.

The sterilizers resemble small standpipes in appearance, and are

made of glaze-lined flanged iron pipe, each length of which is about three feet in diameter and three feet high. Ten such lengths are used in each column. The water and ozone enter the sterilizers at the bottom and pass upward. To insure a thorough mixture, there is placed at each joint a screen or false bottom, which consists of a plate of celluloid with holes $\frac{1}{30}$ inch in diameter. There are 126 such holes to the square inch. To avoid undue pressure upon the screens and a reduction in the flow which would result from the small area of the holes, by-passes are arranged to carry a part of the water around the joints. Peep-holes of glass are set in the sides of the sterilizers, through which a view can be had of the mixture of ozonized air and water. The distribution of small bubbles thus observed is very complete. The frictional resistance offered by the sterilizers to the passage of the water is said to be less than four feet. The electric power required to ozonize the air was given to me as 4 H. P. per 1 000 000 gallons of water.

The largest system of ozonization thus far installed is at Paris. There a plant with a designed capacity of 3 170 000 gallons of sterilized water per day has been in operation more than a year.

The plant is situated at Saint Maur-les-Fossés, where a waterworks station with pumps and English filter beds had previously been established to purify the water of the Marne for the city of Paris. The ozone generators and sterilizers are substantially like those at Blankenberg. There are three sterilizing columns, composed of twelve sections each. The water escapes at the tops of the columns and flows out by gravity into a small open tank at a level of perhaps eight feet above the level of the filter beds. The water after ozonization is bright and clear and without odor or taste.

The bacterial character of the Marne after filtration and ozonization was reported upon for the information of the Dutch Government by Dr. Ferdinand Begançon, Chief of the Bacteriological Laboratory of the University of Paris, under date of January 12, 1899. Of twelve samples of water treated with ozone which he collected, all were sterile after two weeks at 20° C., in gelatine. Of ten samples sown in broth and kept for two weeks at 37° C., two developed the *bacillus subtilis;* the rest were sterile. Another analysis made by Dr. Begançon a month earlier gave identical results.

The cost of sterilizing the Marne water at Paris after filtration has been given to me as $5.90 per 1 000 000 gallons, which includes operating expenses, interest charges, and salaries, as follows: —

ITEMIZED COST OF STERILIZING FILTERED MARNE WATER AT PARIS.

Energy required for ozonizer	3.0	H. P.
" " " air pump	1.5	"
" " " water pump	12.0	"
Total energy	16.5	H. P.
Cost per day, at 2 cts. per H. P. per hour	$7.90	

Other daily expenses are: —

Salaries of three men @ $200 per month	$6.66
Interest charge of 3½% upon $20 000 (cost of plant)	1.94
Interest charge of 4% upon $20 000 (to cover depreciation)	2.22
Total salaries, etc.	10.82
Cost of energy, as above	7.90
Total cost of ozonization per day	$18.72

Capacity of plant, 3 170 000 gallons per 24 hours.

In concluding this very brief review of some of the main facts which have been brought out in connection with the ozonization of water, it may be of interest to quote a few words from a report which was made to the city of Lille regarding the feasibility of employing a system such as has been described to sterilize its water supply.

It will be remembered that Lille is a city of about the size of Detroit, with say 200 000 inhabitants. The report is dated February 12, 1899, and signed by a commission of five experts, among whom was Dr. Roux, one of the directors of the Pasteur Institute of Paris. The findings of the commission were based upon tests with an experimental plant which extended from December 10, 1898, to February 12, 1899. Among the conclusions are the following, taken from a free translation of a copy of the original document: —

1. "The method of sterilizing drinking water based upon the ozonizers and sterilizing column . . . has an efficiency which is undeniable and superior to that of any other process of sterilization known which is susceptible of application to large quantities of water.

2. "The simple arrangement of the apparatus, its strength, the uniformity of its output, and the regularity of its action give every assurance that it is in fact an industrial apparatus.

3. "All the pathogenic and saprophytic microbes that were contained in the water studied by us have been entirely destroyed by the passage of the water through the ozonating column. Only some of the germs of the *bacillus subtilis* were able to resist it successfully.

"We have counted about one germ of this species in 15 c.c. of water after treatment with a mixture of $\frac{1}{2}$ of 1 per cent. of ozone in air. With a concentration of $\frac{3}{4}$ of 1 per cent. the number of germs of *bacillus subtilis* capable of reviving in a bouillon culture medium is reduced to less than 1 in 25 c.c. of the water treated.

"It is necessary to observe that the *bacillus subtilis* (microbe of hay) is entirely inoffensive to man and animals, and that the germs of this microbe resist for the most part methods of destruction; that of the heat of steam, for example, under pressure at 110° C. It is not necessary to destroy them completely in drinking water, and we consider as very sufficient the sterilization obtained by air ozonized with a concentration of $\frac{1}{2}$ of 1 per cent. under the conditions arranged. . . .

4. "The ozonization of water does not introduce any foreign element prejudicial to the health of those required to use it."

Very recently there have appeared in foreign journals some accounts of an experimental research conducted by Dr. Th. Weyl, into the sterilizing value of ozone and of ozone in connection with metallic iron. In the experiments with iron and ozone, the water was treated in such a way as to form a precipitate of ferric hydrate. It was found that water treated in this way was more efficiently purified than by simple ozonization or by treatment with iron and subsequent aëration. With iron and ozone, 87 per cent. of the bacteria were destroyed or removed; with iron and air, 61 per cent. disappeared, and with ozone alone there was a reduction of 5.9 per cent. The original number of bacteria was 45 360 per c.c.

It is to be regretted that Dr. Weyl has not stated what part of his results are due to ozonization and what to coagulation — two very different phenomena. Until this has been determined it would seem preferable to leave the question of the ozone-iron treatment for discussion under another heading, for it is evident that the iron precipitate must be eventually subsided or filtered off, and that provision must be made similar to that necessary for the disposal of the flocculi which result from the treatment of water by alum, before the water can be considered purified. Dr. Weyl is very sanguine of the future of ozonization, as indeed are many of the investigators who have examined the sterilizing action of ozone in water.

Some experiments which I have made with ozone have had as much reference to a reduction in color and odor in water as to its sterilization, for it seemed that the very thorough investigations of

Ohlmüller, Van Ermengem, Marmier, and Roux proved beyond doubt the germicidal capabilities of the process.

The plant with which my tests were carried on was located at Columbia University, and consisted of electric apparatus for the generation of ozone and various cylinders and other vessels in which the ozone-water contact was brought about.

I found that waters in which colors and odors were artificially produced were very greatly improved by the ozone treatment. Colors as dark as 6.0 of the platinum-cobalt scale, produced by soaking dried leaves in distilled water, were reduced to 1.0. Browns, reds, and greens were bleached without difficulty. Even the color of strong solutions of alkaline and acid litmus, indigo and alizarine, were easily destroyed.

The odor experiments were conducted with samples of distilled water in which various odors, such, for example, as that of herring, cinnamon, onion, geranium, and putrid beef, were induced. Ozonization removed the strongest natural odors that could be found.

When experiments were made with naturally colored waters very similar results were observed. With Croton water it was possible to reduce the bacteria 74.8 per cent., the permanganate figure 12.5 per cent., the color 35.1 per cent., and the odor entirely, by passing ozonized air containing 0.3 per cent. of ozone for fourteen minutes through it.

It will be observed that there are two steps to the process of ozonization, — the production of the ozone and its application to the water.

Theoretically, a complete plant consists of filters, dryers, and coolers to prepare the air for treatment; an alternating current dynamo, transformer, and ozonizer to convert the oxygen; a pump to keep the air in circulation, and a sterilizer in which to apply the ozonized air to the water. Conditions which favor the production of ozone are great dryness and very low temperature of the air, and its continued exposure to the electric flame. Sparking in the electric apparatus occasions loss of ozone by converting it back to the more stable form of atmospheric oxygen. Theoretically, it should be better to exhaust the air from the ozonizers than to force it through under pressure, and this is the method now generally employed. Owing to the corrosive action of ozone, it is forwarded to the sterilizers in glaze-lined pipes, although when the gas is perfectly dry such a precaution should not be necessary. In the absence of moisture, metals and organic matters

are not very readily attacked. Owing to its instability, ozone cannot be compressed or stored to advantage.

Two methods of applying the ozonized air to the water have been patented in the United States by Schneller and Van der Sleen, two men who were very actively concerned in the conduct of the Oudshoorn experiments. It may be said, however, in regard to these patents, that they specify definite forms of apparatus with which the inventors consider the system should be carried on.

Of prime importance in applying ozone to water is the necessity for bringing about a very thorough contact. Owing to its purely chemical character, ozone is very certain to attack the most easily oxidizable matters first. Its action upon bacteria is therefore modified by the presence of less resistant substances. Impurities which are most uniformly distributed, such as coloring matters, for example, will not fail to be affected by even small amounts of ozone, but bacteria which are associated with masses of solid matter in water will be difficult to destroy.

The cost of purifying 3 000 000 gallons of water per day by the use of ozone has been given as $6 per million gallons, reckoned on the basis of a plant of upwards of 3 000 000 gallons capacity. Smaller plants have usually indicated a higher price than that stated, but it would appear safe to consider the lower figure to be more exact from the fact that it has been obtained under more strictly practical conditions. If we consider that it is necessary to filter water thoroughly before applying the ozone, and that the cost of filtering will be approximately $10 per million gallons, we will have $16 per million gallons as the total cost of treatment. It will be remembered that sterilization by heat was advocated a few years ago by a prominent engineer of the middle West who considered it would cost $250 per million gallons.

It is very possible, under the conditions which exist at some of our American water works, that ozonization could be applied at a much lower cost than the data which have come to us from Europe would indicate. It would appear that other forms of sterilizers could be built, and that the loss of head which appears to be a considerable factor of expense in the operation of the Blankenberg and Paris plants could be reduced.

It is a question, however, whether there is an important field for the ozone treatment if it must be applied to waters previously filtered as carefully as has been the case in Europe. We are in the habit of

considering that waters which are filtered by English sand beds or mechanical filters are adequately purified, and it is doubtful whether an expense approximately equal to half the cost of filtration would be justified in a supplementary treatment of such waters.

But the ozone treatment presents other claims for consideration than those which rest merely upon sterilization. As a purely chemical agent capable of producing rapid oxidation it appears to me that there lies open for it a promising field in water purification. Used in connection with iron it is possible for ozone to be of assistance in forming a flocculent precipitate for the coagulation of turbid waters. With ground waters containing iron, it should be of special service where simple aëration is not sufficient to precipitate. In the removal of color caused by the presence of organic impurities, and of odor due to microscopic organisms, ozonization could, in my opinion, be frequently applied to great advantage. In such directions, however, there is much need of careful experimental study in order to determine the conditions upon which ozonization can be most effectively and economically applied.

Discussion.

Prof. Leonard P. Kinnicutt.* I think we are all very greatly indebted to Dr. Soper for the interesting account he has given us of the ozonization of water. Many of the facts he has given are entirely new to me, and are the results of his own careful investigations. I agree with him that the greatest opportunity for the use of ozone with water is in the removal of color and odor, and the point which he touched on last, the formation of flocculent precipitates without the addition to the water of anything that can in any way be injurious, is certainly very suggestive. Can we by means of iron and ozone, or by some other substance in the place of iron, produce in water a flocculent precipitate which will carry down with it, as alum does, the organic impurities and the bacteria contained in the water? This is a question which offers an opportunity for a large amount of original research.

Dr. Soper has shown us very clearly how water can be sterilized by the use of ozone, but I did not make out from his paper how much of the organic matter contained in a water could be thus removed,

* Professor of Chemistry, Worcester Polytechnic Institute.

and I should like to ask if he can give us an idea, judging from the albuminoid ammonia or the oxygen consumed, of the amount of purification that has been obtained by the ozone treatment.

The cost of treating water by the ozone method Dr. Soper stated as being about $16 per million gallons. This of course makes the process a very expensive one, and it seems to me that before it can become a practical process the cost must be reduced. This can be accomplished if we can reduce the price of obtaining ozone, and the question presents itself, Is there not a hope that in the future a cheaper method than that of passing silent electrical discharges through air, by which only about one fourth of one per cent. by volume of ozone is obtained, be discovered?

Only this last year a new method of obtaining ozone has been published, — the addition of fluorine to water. Fluorine itself is a gas, which was first isolated by the French chemist Moissan in 1886, and he has now shown us in connection with the properties of this gas that if it is added to water, oxygen is obtained which contains about fifteen per cent. of ozone. This method for obtaining ozone is not at the present time a practical one, but it shows that it may be possible in the next ten or fifteen years to find a method for producing ozone at a very much less cost than that at which it can now be obtained by the silent discharges of electricity through dry air. If this were achieved it would make the ozonization of water a practical process, and one which in many ways could be used to great advantage in the purification of water.

Dr. F. S. Hollis.* Dr. Soper's paper has been full of interest to me, and I think I have learned many things from it concerning the application of ozone to the purification of water. In regard to the disappearance of the odors which were added to the water, I don't know as I understand quite how long that took, or how much ozonized air was allowed to bubble through the liquid in order to drive off the added odors. That is a question I would like to ask.

Dr. Soper. In reply to Dr. Hollis I will say that the amount of ozonized air required to drive off odors is rather considerable. The probability is that the ozone is not wholly responsible for the beneficial effects, and that aëration alone would remove a part of the odors. The activity of the ozone is responsible to a very considerable extent in the case of odors which are known to be refractory to aëration. I think I have some data as to the amount of air required for some unit

* Biologist, Metropolitan Water Works.

of water, and I will be pleased to give the information if I can find it among my papers before the discussion is finished.

Mr. H. W. Clark.* There are one or two things I would like to ask Dr. Soper about his very interesting paper. A very long article is published this week in *Engineering News*, which undoubtedly Dr. Soper has read, — a translation from a German paper, in regard to the meeting at which Dr. Theodore Weyl read his paper upon the ozonization of water, together with a discussion of the paper by several engineers in charge of sand filtration plants. In his paper Dr. Weyl made a statement that plants upon a practical scale were in operation in Belgium, Holland, and Paris. After this paper was read, and during the discussion, Mr. Halbertsma, a Dutch engineer, stated that there was no plant in operation in Holland on a practical scale, and that Tindal's plant in Paris was simply a small laboratory plant. Now, I do not know just when that discussion occurred, but either there was a remarkable ignorance displayed at that meeting in regard to the operation of the large ozonization plants at Paris and at Blankenberg, or else they had later information than Dr. Soper has. I presume Dr. Soper's information is later than theirs, however.

Then another thing, Dr. Soper, in regard to your experiments at Columbia University, I think you said that with waters which you had colored artificially you were able to eliminate 75 or 80 per cent. of the color, and even more in some cases; but when you applied the process to a natural water, that is, I presume, to the Croton water, you only eliminated 35 per cent. of the color. That, of course, is an amount which ordinary sand filters will take out, running at their usual rate. And then, in regard to the plant at Paris, I do not think you gave figures showing the percentage of removal of bacteria by the preliminary filters, and how many bacteria the ozone really had to kill to sterilize the filtered water, what percentage it was of the number in the raw water as it went to the filters. Those are two or three points I should like to have a little more information about.

Dr. Soper. Replying to Mr. Clark's questions, I think I might point out that the discussion before the society of German waterworks people was rather unfortunately produced, and that the subject of ozonization was not considered fairly upon its merits. Dr. Weyl is an enthusiast, and although he is a chemist and hygienist of some repute in Europe, he was not especially tactful nor discreet in the way

* Chemist, Massachusetts State Board of Health.

he brought about the discussion. He claimed at the outset that the efficiency of natural filters had been overrated, and that because of misplaced public confidence in them they had been the means of producing severe epidemics of disease in Europe, and that they were really a very dangerous institution instead of a means of protection. And that claim, rather stoutly presented, at once aroused the indignation of the German water-works superintendents and engineers, who had done a great deal to develop sand filtration, and, I may say, who knew very well that their sand filters were largely efficient, and had not been misrepresented as to their ability to protect the consumers against outbreaks of epidemic. I do not remember that Mr. Halbertsma said that there were no ozone plants in operation in Belgium.

MR. CLARK. No, he did not.

DR. SOPER. He did say that there were none in Holland where Baron Tindal came from, and he pointed that out in a sarcastic way as being significant of the inconsequence of the ozone system. As to the experimental nature of the Paris plant, I have only the figures which I have given, and I have no doubt many of them are not at all new to Mr. Clark, or to very many of the other gentlemen present. The plant is considerably larger than that at Blankenberg, and the amount of water treated at Paris has been stated in French periodicals.

As to the experiments at Columbia University with color, I did say that very dark colors could be removed almost entirely by the ozone system and that I had removed them. I did not say that that could be done upon an economical basis. Such colors as I experimented with would no doubt be darker than those ordinarily met with in water-works practice. I stated that a certain amount of color could be removed; if I remember rightly it was 35 per cent. or so, and other improvements made in the water under conditions that were practical, and that the treatment could be applied, as I applied it, to a water like the Croton water, which was filtered. If I have neglected any point, Mr. Clark, will you kindly suggest it again?

MR. CLARK. I would like to say in regard to the Paris plant that I have understood it was of the size you have described. I simply wanted to know whether it was not in use at the present time, or had not been in use for the past few months, and it was for that reason that Mr. Halbertsma made that remark, and whether you had any later information than what has been published within six months or a

year in the French journals. One other question I asked in regard to the Paris plant was as to the percentage of bacteria removed by the filters, and how many the ozone had to kill to sterilize the water.

Dr. Soper. I might state that I think that Mr. Halbertsma's reference to the Paris plant was to an experimental plant that was set up at the Hygienic Exposition, and that the operation of the present plant, which I have referred to, has been, perhaps, a little more recent than Mr. Halbertsma's information. There have been no experiments made with either the Blankenberg plant or the Paris plant, so far as I know; at all events, the results of such tests have not been published. The source from which I obtained the information regarding the quality of the effluent from the sterilizers gave no facts concerning the number of bacteria in the water applied to the sterilizers. The water was considered to be filtered as well as English sand beds ordinarily filter water in France, which is not as well as in other countries, undoubtedly, and it is presumable that there were considerable numbers of bacteria in the water. The principal point seemed to be that the water was practically sterile after treatment.

Mr. Horatio N. Parker.* Mr. President, I should like to refer to an objection which was raised in that discussion before the German engineers, not, perhaps, a practical one, but one to which Dr. Soper may have a ready answer. The point was raised whether it would be safe to take a highly polluted water, — I mean by that one containing an enormous number of bacteria, — and treat it by ozone, and then deliver it directly to the people; whether there would be any ill effects liable to follow from the use of the water.

Then I should like also to know if Dr. Soper has at hand any figures as to how bacteria would behave when introduced into this water sterilized by the ozone process; that is, supposing you were to introduce a culture of typhoid into the sterilized ozone water, what would take place?

And then, furthermore, without wishing to be discourteous at all to Dr. Soper, I should like to ask him whether he has any figures in regard to the color of the water that has been treated by ozone after it has come from the filters; that is, was there a large percentage of the removal of the color subsequently to the sand filtration? I should think possibly somewhere in the work such figures might have been obtained, but unless my memory fails me we have n't been given any such this afternoon. Of course, Mr. Clark has already asked

* Assistant Biologist, Metropolitan Water Works.

that question, and I don't want to embarrass Dr. Soper any by repeating it.

Dr. Soper. Taking the last question first, I am very glad of the opportunity to say that I have here the results of an analysis of the

CROTON WATER BEFORE AND AFTER TREATMENT BY OZONE.

March 16, 1899.

Results in Parts per Million.		Before.	After.
Turbidity		none	none
Color		2.5	1.0
Odor	Cold	none	none
	Hot	none	none
Chlorine		4.0	4.0
Residue on Evaporation		54.	54.
Loss on Ignition		33.	30.
Nitrogen as	Albuminoid Ammonia	.170	.090
	Free Ammonia	.060	.056
	Nitrites	trace	none
	Nitrates	.75	.80
Bacteria per c.c. after 48 hours in neutral gelatine		416	44

EFFECT OF OZONE UPON ORGANIC MATTER AND BACTERIA IN CROTON WATER.

Date of Collection, 1899.	Period of Ozone-Water Contact.	PERMANGANATE.			BACTERIA PER C.C.			COLOR.		
		Before	After.	% Dif.	Before.	After.	% Dif.	Before.	After.	% Dif.
March 14	10 min.	1.8	1.7	5.5	560	320	42.8	1.50	1.00	30.0
March 21	15 ,,	1.9	1.6	15.7	721	91	87.5	2.00	1.00	50.0
March 28	20 ,,	1.9	1.5	20.5	3 938	512	86.9	2.00	1.00	50.0
March 29	10 ,,	1.9	1.65	18.1	483	216	56.3	2.50	1.00	60.0
April 7	10 ,,	1.7	1.6	8.5	13 018	2 373	81.9	2.00	1.75	12.5

Croton water, made in March, 1899, in which the color was reduced from 2½ to 1 after filtration. In regard to the albuminoid ammonia point, which was raised by Professor Kinnicutt, the albuminoid ammonia was reduced from .170 to .09. The results of several analyses are given in the accompanying tables. As to the ill effects of drinking

water which had been treated with ozone, I would refer to the report signed by Dr. Roux, among others, in the case of the recommendations to the city of Lille, in which he says that there are absolutely no ill effects produced. To amplify that point somewhat, I might say that pure water is not considered a solvent for ozone. Ozone probably does not remain in solution in distilled water at all; perhaps very slightly in solution in waters that contain some organic or mineral constituents. But the effect, so far as it has been observed, after the water has stood for a few moments subsequent to the ozone treatment, is a slight increase in the dissolved oxygen. The ozone, if it were in solution and there were any organic matters, would soon be absorbed by the organic matters in process of oxidation.

In regard to the planting of typhoid germs in water which has been treated by ozone, I might say that, although there are no experimental or analytical data upon that point to my knowledge, there is every reason to believe that they would thrive there as well as in water not treated. The ozone process merely aims to sterilize water as heat might sterilize it, so far as the question of bacteria is concerned, so that no permanent germicidal property is held by the water.

MR. PARKER. I think, Mr. President, perhaps I was at fault in the way I put my two last questions. As I understood the question that was raised by the German engineers, it was if the water might be delivered, when it came from being sterilized by the ozone process, without having first been treated by sand filtration, as I understand it was at Paris. I think the point they were after, though it was not made very clear, was — would there be any toxic properties, or mechanical effects which were unpleasant, produced by the bacteria, the dead bacteria, as it were? And my other question referred more as to whether the water would behave more like a spring water from having a culture introduced into it, or more like a river water. Both of those questions would refer to the toxic properties which might be induced by the growth of the bacteria, rather than to the ozone directly. Have I made that clear, Dr. Soper?

DR. SOPER. I think I understand the point. If the water were not filtered, but were treated with ozone, it would probably not be sterilized, unless it was very clear to begin with. The action of the ozone would be irregular, and a good deal of the power of the gas would be consumed in attacking masses of solid organic matter. As to the production of toxic properties, perhaps some of the experiments that were conducted at Oudshoorn might have bearing. After deter-

mining the sterilizing capacity of the plant, it was determined to test the effect of ozone upon the poisonous products of bacteria, and for that purpose the toxine of tetanus was obtained from the Pasteur Institute of Paris. The toxine was diluted to one fiftieth concentration, and then a portion of it was injected into a mouse. The dose was one half of 1 c.c., as I remember it. The mouse died immediately. The solution of toxine was then subjected to the ozone treatment for ten minutes, after which doses of 1 and 2 c.c. and upwards were injected into mice without ill effects. I should like to answer the gentleman's question as clearly as possible, and if I am not quite on the track, I would be glad to be put on it.

Mr. Parker. I thank Dr. Soper very much for his information. It is exactly what I was after.

Mr. J. C. Haskell.* Mr. President, I would like to ask Dr. Soper why it would not be better to submit water to this treatment before filtration instead of afterwards? If we submitted it to the filtration process afterwards, all of these dead bacteria that have been killed by this treatment would be practically eliminated from the water, and without doubt it is easier to eliminate dead bacteria through filtration processes than live ones. I would like to ask Dr. Soper if he has any data by which he can tell which process is the more beneficial, — submitting the water first to the ozone treatment and then to filtration, or first to filtration and then to ozone?

Dr. Soper. Mr. President, I would reply to Mr. Haskell's question by saying that it hardly seems that the process of treating water before filtration with ozone is to be considered efficient, unless, as I may have said before, the water is very clear. Because, unless we intended to remove color or odor, it would be an irregular process, and sterilization would not be constant. It can be readily seen that small particles of mineral or organic matter afford hiding places for bacteria which it would be very difficult for ozone to reach. The more thorough the mixture of the gas and the water, the more thorough is the process. And in order to kill the bacteria they must be brought in contact with the gas or ozone. If there are particles of solid matter floating about in the water, the gas cannot be readily made to reach the centers of those masses; and if the masses might be conceived to be composed of organic matter, the envelope of organic matter holding bacteria inside would have to be oxidized before the ozone would attack the bacteria. So far as I know, there have been

*Superintendent, Lynn Water Works.

no experiments made on that point, excepting, perhaps, those of Ohlmüller, who pronounced very decidedly that waters which held much organic matter in suspension were difficult to sterilize.

Mr. George F. Chace.* Mr. President, several years ago a paper analogous to Dr. Soper's was read before the Association by Dr. Drown, on the electrical purification of water. The conclusion of Dr. Drown at that time was, that electrical purification of water on the large scale necessary for public water works was impractical. Dr. Soper has dropped a hint that it is either necessary or desirable that there shall be filtration of the water before it is subjected to the ozone process. Now, mechanical purification of water has been shown to be efficient, and if that is the case, what advantage is to be derived from the subsequent use of ozone?

Dr. Soper. The advantages are not merely the benefits which might come from the sterilization of water. That, perhaps, was an important application, as viewed from the standpoint of the people of France and Belgium, where the system has apparently met with approval; but it would seem that important fields for the introduction of ozone lay in the removal of color and odor. If at the same time a reduction can be made in the bacteria which, taking a conjectural case, might come from a filter imperfectly operated, so much the better.

In reply to Dr. Hollis' question as to the amount of ozonized air required for water, I may say that the data I have given as my own for the treatment of Croton water are one cubic foot of air used for the treatment of 25 gallons of water. The contact in that case was not perfect. With an efficient contact, the ozone would be absorbed in the water, and there would be no escape of ozone at the end of the mixture. There was a decided escape of ozone in the experiments I refer to, because it was not found feasible to bring about a sufficiently intimate mixture of the ozonized air and water in the small laboratory apparatus.

The President. Is there to be any further discussion upon Dr. Soper's paper at this time? If not, in behalf of the Association, I desire to thank Dr. Soper for the information he has given us.

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*Superintendent, Taunton Water Works.

THE CONSTRUCTION OF THE FELLS RESERVOIR FOR THE METROPOLITAN WATER WORKS.

BY JOHN L. HOWARD, ASSISTANT ENGINEER, METROPOLITAN WATER WORKS.

[*Read February 14, 1900.*]

Under the provisions of the act creating the Metropolitan Water Board, it was provided among other things that on or before January 1, 1898, the Board "should provide a sufficient supply of pure water for the following named cities and towns of the Metropolitan District and the inhabitants thereof, to wit: The cities of Boston, Chelsea, Everett, Malden, Medford, Newton, Somerville, and the towns of Belmont, Hyde Park, Melrose, Revere, Watertown, and Winthrop." Since the passage of the act the number of places supplied by the Metropolitan Water Board has been increased by the admission of the city of Quincy, and the towns of Nahant and Arlington. Swampscott is also supplied with water, although not a part of the Metropolitan Water District.

For the purpose of furnishing water to the higher portions of the cities and towns on the north side of the Metropolitan District, whose water supply was divided into high service and low service, and to furnish the entire supply for those places where there was no division in the distribution system, it became necessary to build a pumping station and reservoir on the north side to furnish to those places a supply of water similar to that given to the city of Boston and places to the south and west by the Fisher Hill Reservoir and the high service pumping station at Chestnut Hill Reservoir.

In searching for a suitable location for a reservoir on the north side of the city, and considering the necessary requirements of such a site, attention was naturally directed to a large area of land already in the possession of the Commonwealth for a public park reservation, known as the Middlesex Fells. After some discussion and several surveys, an area of land near the southeastern corner of the reservation was selected. It was quite centrally located to the cities and towns of the northern Metropolitan District on the north, south,

FIG. 1. —SITE OF FELLS RESERVOIR AFTER CLEARING.

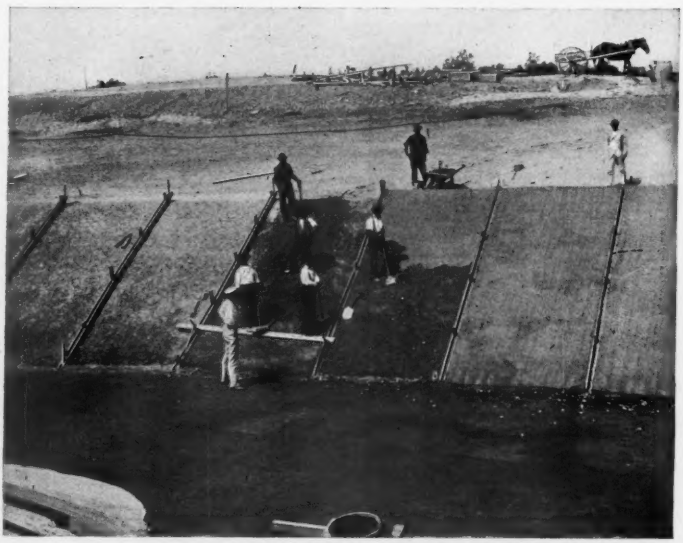

FIG. 2. — PLACING CONCRETE ON SLOPES.

and west, and on the easterly side only Winthrop, Swampscott, and Nahant are outside the limits of a four-mile circle drawn from that point as a center. Its elevation was above that of any supply in use by these cities and towns, so that no place should be supplied with less pressure than formerly. It was about 270 feet above Boston city base, and was originally an alder swamp (Plate I, Fig. 1), requiring only the excavation of material and the building of five short dams, at as many outlets, with an aggregate length of 982 feet, to turn it into a reservoir of about 42 million gallons capacity, covering 8.52 acres.

While engaged in making a survey of the proposed site, numerous rod soundings and wash borings were made and test pits were dug, in order to furnish a better basis for an estimate of quantities, and also to give the contractor as much information as possible before bidding on the work.

The area covered by this survey was about 15 acres in extent; the area within the proposed dams was about 10 acres, and in this area there were made about 500 rod soundings, 40 wash borings, and 40 test pits, which is about 50 soundings per acre or one sounding for each 900 square feet. On the proposed locations for the dams, soundings were taken at intervals of 25 feet on the center lines, in order to definitely determine the surface of the rock.

Soundings at different points in this swamp showed pockets of mud from 12 to 20 feet in depth below the surface, or to grade 245 and 238, but the soundings on the location of the proposed dams showed rock above elevation 245 in all cases. Before determining on this location for the reservoir, the opinion of a geologist was secured regarding the imperviousness of the surrounding rock, and its general fitness as a reservoir site. After a study of the site and a consideration of the data submitted, it was reported that from a geological standpoint the rock and seams would probably be practically water tight, and that the site seemed a suitable one for reservoir purposes. The report stated, however, that it seemed probable that the surface of the rock as indicated by the borings would be found to be incorrect; that the borings showed a rock bowl on the summit of a hill with no point in the surface of the enclosing rock as low as points in the muck holes inside the bowl, and that if it should prove to be true it would be a curiosity from a geological standpoint. That is, there were pockets of mud in one case down to elevation 238½, but the lowest point shown by the borings on the

line of the dams was at elevation 246. The result vindicated the correctness of the scientific theory and demonstrated again the fact that depending absolutely upon borings for the surface of the rock is not always a wise proceeding. In one place, at the point shown by our borings, with rock at an elevation of 260, it was actually found at 238½, about 22 feet lower than shown.

In Fig. 1 the rock as found is shown by the dotted lines; and the full line shows the rock surface as plotted from the soundings and shown on the contract drawings. The narrow seam of earth shown on the profile of Dam No. 5 is something that could not be expected to be found by borings, but it is somewhat surprising that the profile of Dam No. 2 should show such a variation from the contract drawings. The places where the dotted lines rise above the full lines are caused by slight changes in the location of the dams to avoid seams or rotten rock. These changes will be shown more clearly in Fig. 2.

In Fig. 2 the full contour lines show earth elevations above 271 and the rock contour at elevation 250 as plotted from the soundings. The dotted lines show the location of the dams and the water line as built, and the rock surface as actually found at elevation 250. The 250 contour lines agree as closely as could be expected, perhaps, except at the northwesterly corner of the west basin and on the easterly side of the east basin near Dam No. 4, the greatest variation being about 50 feet. These variations when summed up, however, were sufficient to increase the capacity of the reservoir from 38,500,000 gallons to 41,350,000 gallons, or a little over seven per cent.

The area selected was naturally divided by a point of ledge into two nearly equal parts, and by utilizing this rocky ridge and building two short division walls, one on the south end 108 feet long, and one on the north end 53 feet long, two basins were formed when the reservoir was drawn down six feet, so that when it became necessary to clean the reservoir one basin would be available for use at all times.

In the design of the reservoir it was intended to remove all earth and vegetable matter from the ledge, and to cover the surface of the bottom, and the embankments, with concrete and stone, so that at no point would the water come in contact with anything likely to promote the growth of organisms, or furnish food for them. Several points of ledge extended nearly up to high-water level at different places in the reservoir, and it was thought best to remove all of this rock above grade 265, so as to give a minimum depth of six

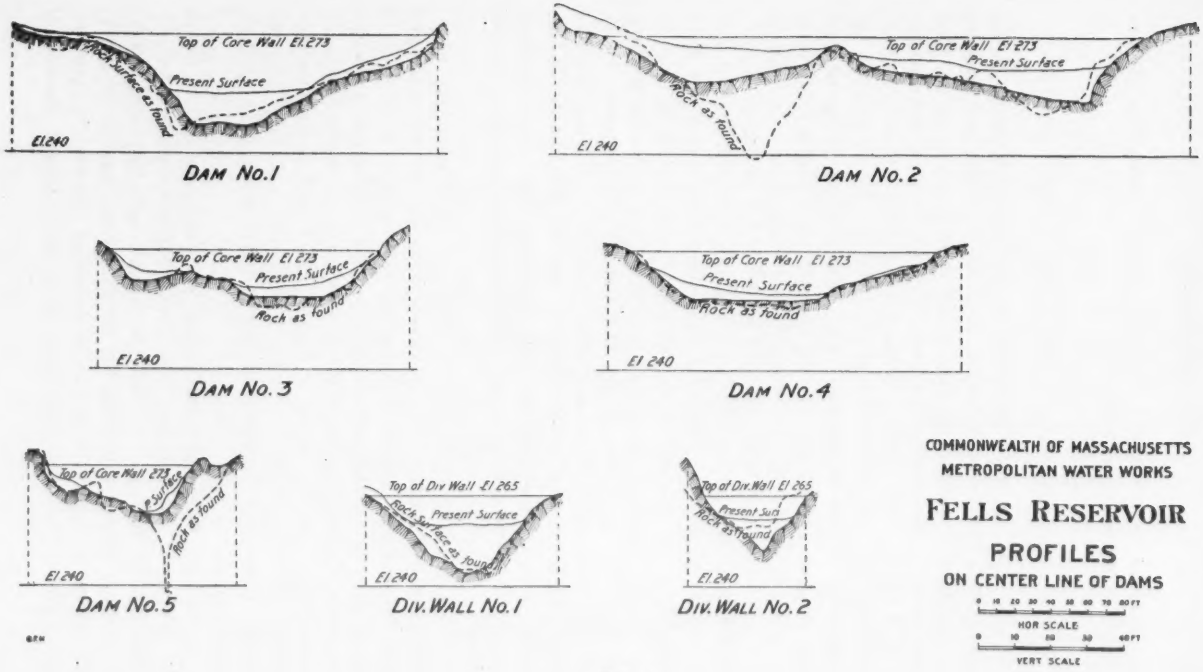
Top of Core Wall El 273
Present Surface
Rock Surface as found
El 240
DAM No. 1
Top of Core Wall El 273
Present Surface
Rock as found
El 240
DAM No. 2
Top of Core Wall El 273
Present Surface
Rock as found
El 240
DAM No. 3
Top of Core Wall El 273
Present Surface
Rock as found
El 240
DAM No. 4
Top of Core Wall 273
Rock as found
El 240
DAM No. 5
Top of Div Wall El 265
Present Surface
Rock Surface as found
El 240
DIV. WALL No. 1
Top of Div Wall El 265
Present Surface
Rock as found
El 240
DIV. WALL No. 2
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER WORKS
FELLS RESERVOIR
PROFILES
ON CENTER LINE OF DAMS
0 10 20 30 40 50 60 70 80 FT
HOR SCALE
0 10 20 30 40 FT
VERT SCALE

FIG. 1.

feet of water in the basins when full, and do away with shallow flowage as much as possible.

RESERVOIRS AS PARTS OF PARK SYSTEMS.

During the last few years the use of reservoir grounds in the Metropolitan District by the public as portions of the park systems has increased to a surprising extent, and there seems to be no good reason why landscape considerations should not be given more weight in their design. The opening of the various electric lines to the outlying districts, the use of the bicycle, and the development of the boulevards by the Metropolitan and Boston Park Commissioners have all tended to increase the use of reservoir grounds by furnishing pleasant and convenient means of access to them. It is probably safe to say that within the last ten years the use of the Chestnut Hill Reservoir grounds by the public has increased tenfold, and it is by no means improbable that by the time the heart of the Fells reservation can be reached as easily as Chestnut Hill is now by the electric cars, running through parkways, and as this great reservation on the north side of the city becomes better known to the public, this place in connection with Spot Pond will be a pleasure resort for large numbers of people; and for this reason it was thought wise to depart slightly from the usual form of construction in order to improve its appearance and keep it more in harmony with its surroundings.

It is usual in designing a dam to select a point where the quantity of material required for its construction will be the least, and after determining a safe section for the embankment to build it of the required dimensions, and, bearing in mind the fact that a straight line is the shortest distance between two points, to make it usually with straight and even slopes of $1\frac{1}{2}$ to 1, 2 to 1, or 3 to 1; sometimes with a berm to break the slope, if the dam is a high one, but usually presenting to sightseers the outward form of a railroad embankment.

In the case under consideration, it was finally decided to follow the designs of the landscape architects who had already been consulted by the Metropolitan Park Commissioners in their work, as far as possible without sacrificing the essential requirements for waterworks purposes and without adding unduly to the cost of construction. The outlines of the dams were made curved instead of

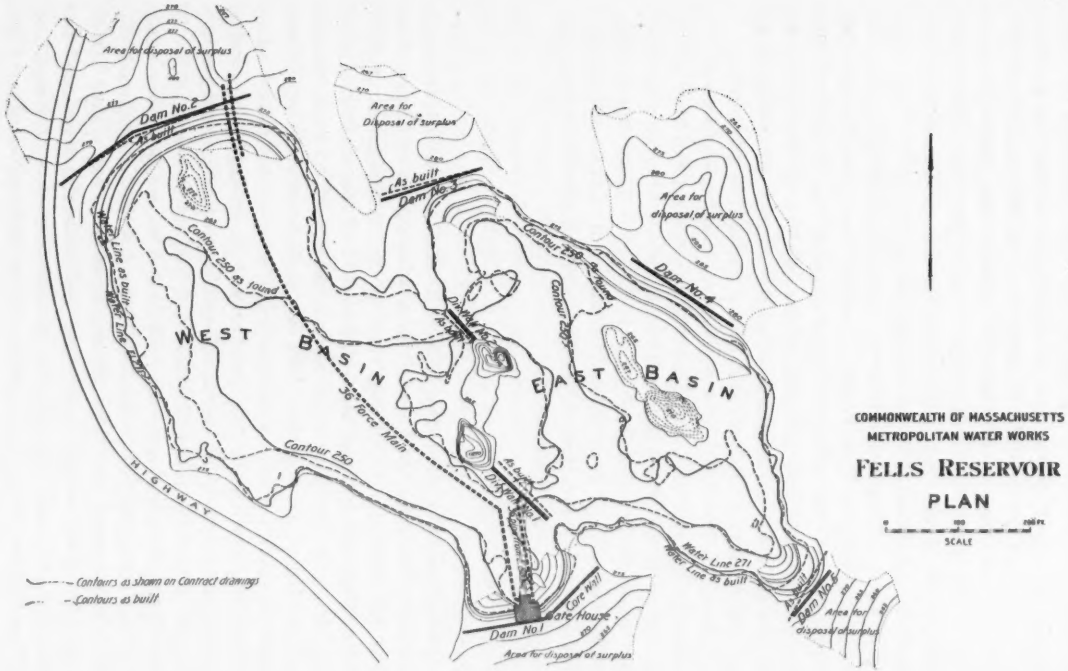
Area for disposal of surplus
Dam No. 2
As built
Area for Disposal of surplus
As built
Dam No. 3
Area for disposal of surplus
Contour 290 as found
Contour 290 as built
Dam No. 4
Line as built
Water Line 271
WEST BASIN
EAST BASIN
Dam No. 5
As built
36" force Main
Contour 250
HIGHWAY
Dam No. 5
As built
Water Line 271
Water Line 35 built
Core Wall
Gate House
Dam No. 1
Area for disposal of surplus
Dam No. 6
As built
Area for disposal of surplus
Contours as shown on Contract drawings
Contours as built
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER WORKS
FELLS RESERVOIR
PLAN
SCALE

FIG. 2.

straight, some with fairly regular curves, others decidedly irregular, and all joining the original rock surface as naturally as possible. There was a large quantity of material to be disposed of, 100 000 cubic yards of earth and 8 000 cubic yards of rock, and in order to better conceal the dams this surplus material was piled in their rear, in one place 25 feet high, and the surface was graded so as to run smoothly and naturally to the original ground.

The supply to the reservoir comes through a 36-inch pipe from the pumping station at Spot Pond. Provision was made for doubling the capacity in the future, by laying a second line of 36-inch pipe through the core wall and dam at the inlet of the reservoir, and through the wall of the gatehouse at the outlet. All water, either entering or leaving the reservoir, passes through the gatehouse.

The site of the reservoir is in a natural woodland surrounded by outcropping ledges on all sides, and the general appearance of the place is decidedly wild and uncultivated, and as if miles away from any considerable population (Plate I, Fig. 1). There was no suggestion of artificial surroundings at any point, and it was the aim of the landscape architects to avoid as much as possible all such appearances in its construction.

CONTRACTS.

The contract was let in May, 1898, to T. W. Kinser & Sons for about $51 400. The price bid for earth excavation was 19 cents per cubic yard, and this included cutting, clearing, and grubbing the ground, all pumping and draining, the excavation of all the material except rock, the building of the rolled embankments, and the final disposal and grading of the material. The contractor stated that he did not expect to make a profit on the earth excavation at that price, and he was not disappointed. The weather was exceedingly unfavorable to the prosecution of the work. Possibly many here remember the kind of a working season it was from May to October, 1898. It seemed to rain about every other day, and in one particular case, after the excavation for a core wall was practically completed, the trench was pumped out three different times on as many days before a start could be made. In October the contractor abandoned the work, and with as little delay as possible the work of completing the construction of the reservoir was re-let, and on November 4 the contract was awarded to Nawn & Brock at a price for earth excava-

tion of 51 cents per cubic yard. This price, while considerably above what has been paid in many places for similar work, has proved none too large in this particular case, and it is probable that if the same contractors were asked to bid on a similar piece of work, their price would be increased over what they received on this.

The bottom of the reservoir was established at elevation 250, which is as high as any of the supplies formerly used in this district, and, as the soundings showed the muck extending down to elevation 238, it was decided to remove all muck below the bottom of the reservoir and refill the space with good material from the excavation, thoroughly rolled in four-inch layers with a heavy grooved roller. In the west basin the amount of muck to be removed below the bottom of the reservoir was estimated at 11 000 cubic yards, all in one pocket, and in the east basin there was about as much more, but distributed over a considerably larger area with three pockets, varying from six to eight or nine feet in depth below the reservoir floor.

The contractor believed it would be more economical for him to take out this muck with a dredge, as it was too soft to shovel into carts, and too low to be drained without pumping, and when he tried to pump it out gave considerable trouble from clogging the suction pipe. At considerable expense he erected a Hayward excavator, which is a grapple dredge with a fixed length of boom, and which loads from one side only. With this dredge he loaded muck through a hopper into cars of about one cubic yard capacity, and then the cars were hauled by a hoisting engine in trains of six to the top of the dump and switched along on the dump to the place of disposal. After several thousand yards had been excavated, the edge of the excavation under the dredge caved, requiring the moving back of the dredge before all of the muck had been excavated, and leaving a considerable quantity in the center of the muck hole that would have to be taken out by carts later. The muck taken out by the dredge was so full of water that after its disposal the dump became a quagmire; and although a platform was built under the track to keep it from sinking, after each shower it required more plank and attention to keep it in line, so that the cars could keep on the track. By this time it was seen that the work could not be completed that season in any event, and after cold weather it was found very easy to remove the muck by carts. A sump hole was kept well down in advance of the excavation, the muck was planked over where it went down too steeply to haul out the loaded carts, and of course in

cold weather, when the ground was frozen, it was no trouble to handle the material on the dump.

The rock excavation was divided into two classes in this contract. It was known that a large number of boulders would be found, and on the exposed surface of the ledge in many places were loose and seamy stones that should be removed; so the rock excavation was classified either as loose rock or solid rock. Loose rock was defined as all boulders or loose rock that measured more than four cubic feet and less than ½ cubic yard, and solid rock was defined as all boulders measuring over ½ cubic yard and ledge requiring blasting for its removal. In this case the contractor was paid for all rock that was taken out, even if it was outside the lines given by the engineer. It was thought that as whatever rock was taken out increased the capacity of the reservoir by 200 gallons for each cubic yard removed, ¾ of a cent for each gallon added to the storage capacity was not unreasonable.

DAMS.

The dams were made with a concrete core wall of Rosendale cement mixed 1 : 2 : 5, 3 feet wide on top and with a batter on each side of 1 in 12, bonded into the solid ledge by a trench from 2 to 3 feet deep. The face of the core wall on the side next the reservoir was plastered with a ½-inch coat of Portland cement, put on in two portions, as follows: next the concrete a thick coating of Portland cement mortar mixed in the proportions of one part of cement to one of sand was put on, rubbed to a uniform surface and left rough; over this was spread a coat of neat Portland cement which was thoroughly worked to make a water-tight surface. The embankment surrounding the core wall was made of selected material rolled in 4-inch layers with a heavy grooved roller, without stones over 4 inches in their greatest dimensions. The embankment was built one foot wider on the side next the reservoir than the dimensions given on the plan, and after it had been well rolled and packed this extra foot was taken off before the concrete slope was put on, and paid for as earth excavation. The embankment was 10 feet wide on top, with a slope on the rear side of 2 to 1, and on the side next the reservoir a slope of 4 to 1 to a point 4 feet below high water, and from there to the bottom of the reservoir a slope of 2 to 1. From the bottom of the reservoir to elevation 267, or 4 feet below high water, the surface of the embankment was covered with a layer of

FIG. 1.—COMPLETED DAM.

FIG. 2.—GATE HOUSE.

Portland cement concrete 4 inches thick, mixed in the proportions of 1 : 2½ and 4, with a footing course 1 foot square at the bottom. Above elevation 267, to a point 1½ feet above high water, the embankment was covered with a layer of broken stone 10 inches in thickness; the under 6 inches of this covering was broken stone not more than 2½ inches in greatest diameter, and the upper 4 inches, stones not more than ¾ inch in their greatest diameter; all of the stones were free from dust or other fine material.

All of the dams, with one exception, were built in this manner. The one next the gatehouse, however, was made somewhat more formal. The gatehouse of course was plainly the work of man and not of nature, and for this reason the landscape architects considered that an obvious dam with straight slopes and stone paving would not be out of place. So this dam was built with a straight slope of 2 to 1 from the bottom to the top. The concrete extends from the bottom of the reservoir to a point 6 feet below high-water line, and from there to a point 2 feet above high-water line the dam is faced with stone paving 18 inches thick, the bottom layer being of broken stone and about 6 inches in thickness (Plate II, Fig. 1).

In placing the concrete on the slopes, sets of rails consisting of two 2 x 4-inch sticks with a 2-inch stake between them were laid to line and grade not more than 10 feet apart (Plate I, Fig. 2). Then the space between the rails was carefully graded, and concrete put on as dry as possible and still have the moisture come to the surface after ramming. The surface was left about ½ inch below the top of the rails. Then within an hour a mason went over it with a mortar mixed 2½ sand to 1 cement, and smoothed the surface with a trowel. At first the contractor thought he could nail boards across the rails, and by starting from the bottom and ramming the concrete under the planks and adding one plank at a time secure a fairly smooth surface without having to make use of a coat of mortar afterwards. In one or two instances fairly good results were obtained, but generally after the lagging was removed there were so many places that needed smoothing up and patching that it was thought better to do the entire surface the other way and get a uniform result, as well as being cheaper than using boards, not many of which could be used on a second dam, owing to the difference of the radii of the curved surfaces. Possibly, if the surface of the dams had been straight instead of curved, the boards might have worked better.

On the bottom also a layer of concrete 4 inches thick was placed, made of Rosendale cement; it was not intended to be water tight, but merely to prevent the water from coming in contact with earth that might furnish food for the growth of organisms, and to facilitate the cleaning of the basin. The plastered surfaces of the core walls were relied upon to prevent leakage from the reservoir.

The division walls between the basins were made of Portland cement concrete, 6 feet wide on top with a batter on each side of 1 in 8, and extended down to the solid rock, and were bonded into the rock by a trench about 3 feet deep. These walls were not plastered on the outside, but proved practically water tight under heads of 15 feet, which is all they can ever be called upon to sustain.

The 36-inch force main is carried through the reservoir 2 feet above the bottom on concrete piers, to which it is anchored by means of a 2 x ½ inch wrought-iron strap around the pipe connected by rods and turnbuckles with a 4-inch channel iron buried in the concrete (Plate III, Fig. 1). The grade of the bottom of the pipe, 2 feet above the bottom of the reservoir, was fixed chiefly to save rock excavation in the deep cuts in the approaches at either side of the reservoir; it also facilitates the work of cleaning the reservoir, and permits the water to drain freely to the gutter from the sides of the basin. The gutter is V-shaped, 2 feet wide on the top with a maximum depth of 6 inches and minimum depth of 2 inches, and has a fall of ½ inch in 100 feet.

GATEHOUSE.

The original study for this reservoir provided for two gatehouses, one at the inlet and one at the outlet; but after further consideration it was decided to bring the water through the reservoir in the force main to one gatehouse, from which it could be distributed into either basin, or supplied directly to the cities and towns as desired. The substructure is made of Portland cement concrete. The outside walls are 3 feet 4 inches and 3 feet 8 inches wide on the top, with a batter of 1 in 12; the inside walls have a minimum thickness of 3 feet and are vertical. About a foot from the inlet is a set of three grooves for stop planks or screens; 6 feet beyond are openings on either side at elevation 267, governed by stop planks, to be used when it is not desirable to draw water from the bottom of the reservoir; then a few feet further is a weir 6 feet wide, for measuring the

FIG. 1. — FELLS RESERVOIR BEFORE FILLING.

FIG. 2. — FELLS RESERVOIR, COMPLETE.

flow when desired. Just beyond the weir is a 16-inch overflow pipe, the top of which is set 1 foot above the usual high-water line and connected with a 16-inch drain about 800 feet in length, which discharges into a swamp below the reservoir. The two front chambers are drained by means of 3-inch valves connected by a brass pipe with the 16-inch drain, and the two rear chambers, which will be used in drawing the water from the reservoir when cleaning the basins, have 12-inch valves connected with the drain. A 1-inch brass pipe is laid to each basin and connected with float pipes in the wall of the gatehouse for indicating the height of water in the reservoir on a recording gage. On the rear wall and side wall the concrete foundation extends only to elevation 265, and above that the exposed surface is quarry faced granite masonry.

It will be noticed that a wing wall is shown only on one side of the gatehouse (Plate II, Fig. 2). There was none required on the other side, as the slope from the embankment either met ledge or ran out against the second 36-inch pipe that was built into the wall to provide for an increased future supply. No plastering was done on the walls of the chambers, care being taken to place the finer parts of the concrete next the forms; and after removing the forms the wall came out fairly smooth without showing any stones or cavities on the surface.

The openings in the gatehouse are governed by 36-inch sluice valves operated by hand wheels from the floor. A ratchet wrench is furnished with the valves so that they can be operated by one man under the most unfavorable conditions.

The superstructure of the gatehouse is made of a brown seam-faced stone with granite base and trimmings, and has a tile roof. The inside dimensions on the floor are 27 feet 6 inches × 22 feet 4 inches, with an ell of 12 feet 4 inches × 9 feet 2 inches.

A comparison of the engineer's preliminary estimate of the principal items for the construction of the work and prices for the same, with the prices at which the contracts were awarded, is on page 32.

The amount of the contract using the preliminary estimate of quantities and the prices bid at the first letting was $51 465, and there was paid on this contract $35 038.48. The additional amount of the second letting, using the price bid at that time and the estimated amount of work remaining to be done, was $54 871.50, or $3 406.50 more than the amount of the first bid for the entire work, and there was paid under this second contract $68 836.40.

The total estimate of the engineer for the work was about $103 000, without the superstructure of the gatehouse, sluice valves, and operating machinery, or engineering expenses. The actual amount paid to the contractors on both contracts was $103 874.88; and the cost per million gallons was about $2 500.

METROPOLITAN WATER WORKS — FELLS RESERVOIR.

Comparison of Preliminary Estimate with Actual Quantities and Prices.

		Earth Excavation. Cu. yds.	Loose Rock Cu. yds.	Solid Rock. Cu. yds.	Portland Cement Concrete. Cu. yds.	Rosendale Cement Concrete. Cu. yds.	Portland Cement Plastering. Sq. yds.
Engineer's Preliminary Estimate.	Quantities	100 000	1 000	3 500	1 600	3 500	1 100
	Price	$0.40	$1.00	$2.00	$6.50	$5.50	$0.70
	Cost	$40 000.00	$1 000.00	$7 000.00	$10 400.00	$19 250.00	$770.00
First Contract.	Quantities	54 101	511	5 080	—	1 965.23	691.4
	Price	$0.19	$0.50	$1.75	$5 50	$3.95	$0.25
	Amount Paid	$10 279.19	$255.50	$8 890.00	—	$7 762.66	$172.85
Second Contract.	Quantities	56 750	974	3 370	1 817	2 708	540.0
	Price	$0.51	$0.90	$1.50	$7.00	$5.25	$0.75
	Amount Paid	$28 942.50	$876.60	$5 055.00	$12 719.00	$14 217.00	$405.00
Total, Both Contracts.	Quantities	110 851	1 485	8 450	1 817	4 673	1 231
	Amount Paid	$39 221.69	$1 132.10	$13 945.00	$12 719.00	$21 979.66	$577.85

DISCUSSION.

DR. F. S. HOLLIS.* I would like to say, as something supplementary to Mr. Howard's interesting paper, that it has been my duty to examine the water of this reservoir since it was first filled early in September. Without exception it has been uniformly lower in color and organisms than the water pumped into it, as would be anticipated from the fact that the organisms and the color to a slight extent are decreased by passing through a number of miles of pipe, — in this case, I think, something over twelve miles. With a single exception, which I think was in May, there have been absolutely no local growths in the reservoir since it was filled. There has been no increase, in other words, in the organisms over those put in. From the method of construction, the division of the reservoir into two basins, one of which can be drawn down while the other is in use, and the very clean rock surface and cement bottom, it ought to be possible to keep the reservoir in the most perfect condition as regards the quality of the water stored there.

* Biologist, Metropolitan Water Works.

Mr. Walter H. Sears* (by letter). In connection with this paper, a brief reference to the construction of the dams of the Winchester Water Works, which are in this immediate vicinity and which were built under my direction, may be interesting.

The North Reservoir dam was built in 1873 and 1874, and that of the South Reservoir in 1880 and later.

The north dam, as well as that for the South Reservoir, was built on a curve, as being really the line which required the least amount of earthwork in the embankment. Both dams were built with core walls of stone laid in cement, with a coating of mortar plastered on the water side, and a second coating of neat cement troweled on in a thin layer and then brushed over with a wet brush. This work was done by a skilled mason.

At the south dam a pocket of mud or muck, some sixteen feet deep, was encountered. This muck was entirely vegetable in character, with no stones or gravel except where such may have become mixed in around the sides of the pocket. Incidentally it may be mentioned that the remains of a beaver dam were encountered in this deposit; sticks two inches and even three inches in diameter were found, with the ends sharpened in the manner peculiar to the beavers, still showing the marks of their teeth, although it must have been very many years since these animals lived in this region. These sticks were quite soft when first found, and after a few days' exposure to the air they became full of cracks as the water dried out, so that they could not be preserved.

There was a small brook running through the valley at this time, and it was decided to utilize the same in removing this muck. The stream was dammed temporarily and the water used to bring the muck into a semi-fluid condition, in which state it was allowed to flow into a well or sump, from which it was pumped by an ordinary rotary pump and allowed to flow away down the original channel of the brook or over the ground below the dam site.

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*Civil Engineer, Plymouth, Mass.

WOODEN JOINTS IN CAST-IRON WATER MAINS.

BY WILLIAM MURDOCH, ENGINEER AND SUPERINTENDENT,
SAINT JOHN WATER WORKS.

[*Read March 14, 1900.*]

Water was introduced into the city of Saint John, N. B., through a steam pumping plant, in the year 1837. The jointing of the pipes then was mainly in lead. Some rust joints were made also, and they have remained intact ever since. One of these, which had occasion to be broken about two years ago, was found in perfect condition.

When preparations were being made for the abandonment of the pumping system and the laying of a 12-inch gravitation main 4¼ miles in length, the superintendent of the Saint John Works, Mr. Gilbert Murdoch, was sent to Halifax, about the year 1849, to observe the process there adopted of jointing the pipes with wood, in the introduction of water to that city. As a result, the Saint John pipe, which was completed in the year 1851, was jointed throughout with wood, only excepting such joints, mainly in specials and stop cocks, as were either so large, so small, or so unsymmetrical that the staves would not fit.

A 24-inch main was laid in the year 1857 alongside the 12-inch main, and wood was again used, the proportion of wood to lead being about the same as on the preceding occasion.

Another 24-inch main was laid in the years 1873 and 1874. Turned and bored joints had been invented by this time, and a large number, perhaps one half, of this kind were employed. The remainder of the joints were made some with wood and some with lead.

The experience with these joints has been that the wood has proved the most desirable jointing material. Driven dry and well wedged, on absorbing moisture from the water in the pipe it becomes perfectly tight, the only evidence of the presence of water within being in the mere dampness of the end wood exposed. On the pipes contracting and expanding, under changes of temperature, the elasticity of the wood has allowed of a longitudinal shearing to and fro in the fibers,

whilst the surfaces remained in close contact with the iron, and no leakage took place. The proof of this is in the fact that scarcely ever does a leak occur in a wooden joint.

Lead calking, on the other hand, becomes pulled as the pipes contract, and remains out when they expand again in summer. Another pull is given the succeeding winter, and so on until the pressure overcomes the resistance of the lead and you have a blown joint. To be sure, this process takes place only in plain joints. A groove in the socket will overcome this difficulty, but it will also require more lead.

Turned and bored joints enjoyed considerable popularity for some time. For the information of any who have not seen them, it may be stated that such a joint consists of a slightly tapering turned spigot end fitting accurately into a bored or machine-cut faucet or bell. Such surfaces are well smeared with white lead and the joint slammed home. Some have a slight recess left for the addition of lead if thought necessary, but the recess in our case was not grooved; and the lead where used has often backed out.

The objection to such joints has been that under changes of temperature their rigidity has caused leakage. If laid in warm weather and exposed to the sun, on cooling the pipes shrink and the joints open; and if laid in frosty weather and later on subjected to heat, a socket will now and then burst. They cost more than plain joints, and for the reasons given seldom remain tight.

All of these considerations prevailed upon the writer to use wood for jointing a 24-inch cast-iron pipe, laid by him in the years 1898 and 1899, for the supply of the western district of the city of Saint John.

The length of the main is 5½ miles, and the deepest depression is 166 feet below the level of the lake from which the head is derived.

All of the joints are of pine, with the exception of specials, stop cocks, and other unstandardized connections into which the staves did not fit. These odd joints are of lead. The pressure has been on and the main in operation for about three months, during which time there has been no trouble of any kind.

The contract price of the staves has been 13 cents per joint, and the cost of labor, laying and jointing, about 57 cents per joint, making a total cost per joint of 70 cents. The rate of wages was $1.20 per day.

It must be borne in mind that before covering a pipe jointed with

wood it is necessary to let in the water and examine every joint carefully for leakage. Where a leak occurs, drive a wedge into the wood either flatwise or crosswise, as may be necessary for thickening or for broadening the stave. Once it is wedged up tightly, and the pipe covered over, no further leakage will occur.

As to the durability of wooden jointing material, the accompanying samples will speak for themselves (Plate I, Fig. 1). That marked *A* was taken from the 12-inch main, about four years ago, after having been in use about forty-five years. *B* was removed after about forty years' service in the 24-inch main. Both have been lying on a shelf in dry air for three or four years, yet their varied experience has not induced decay. Indeed, some joints of iron pipe have decayed where exposed to acids and electric currents in the soil, but wooden jointing material has invariably held its own against the ravages of time.

The stave marked *C* is one of the pattern used last year on the 24-inch pipe, of which the following is the

SPECIFICATION.

1. There will be required by the Board of Management of the Department of Public Works of the city of Saint John,

2 400 joints for 24-inch pipe.
250 joints for 12-inch pipe.
80 joints for 10-inch pipe.

2. A joint in each case shall consist of a sufficient number of staves to encircle the exterior surface of a pipe, and the circumference shall be as follows: —

24-inch pipe, 81 inches.
12-inch pipe, 42 inches.
10-inch pipe, 35 inches.

Each stave is to have a length of four and one quarter ($4\frac{1}{4}$) inches, and a thickness throughout of seven sixteenths ($\frac{7}{16}$) of an inch; the outer and inner surfaces are to be concentric, and the sides radial.

3. Each stave is to conform transversely with the curvature of a circle whose radius shall be as follows: —

For 24-inch pipe, radius $12\frac{7}{8}$ inches.
For 12-inch pipe, radius $6\frac{5}{8}$ inches.
For 10-inch pipe, radius $5\frac{1}{2}$ inches.

4. All of the staves are to be made of clear white pine, straight in grain without knots or shakes, worm holes or rot. No stave will be accepted which does not conform with these conditions, and they must be well seasoned and thoroughly dry.

5. All of the staves must be made to the satisfaction of the engineer and superintendent of sewerage and water works for the time being. He will have authority to reject any that in his judgment do not conform with the conditions of this specification, and his decision shall be final. He shall also have the right to explain any supposed ambiguity and to alter any dimensions named herein prior to or during the course of manufacture of the staves, such alteration not to affect the contractor's right to be paid for those already made; and it shall be the duty of the contractor to cause such staves made by him or under his direction to have the exact dimensions so given by the said engineer and superintendent, when stated in writing by the said engineer to that effect.

6. The engineer to have the right to increase or diminish the number of joints to the extent of ten per centum above or below the number herein named in each class, giving notice to the contractor to that effect, in writing, prior to the manufacture of the staves; but should the whole number of any class be made, and the engineer then find that all are not required, the city shall, nevertheless, accept the whole.

A FEW NOTES ON CAST-IRON PIPE.

BY FREEMAN C. COFFIN, CIVIL AND HYDRAULIC ENGINEER, BOSTON.

[*Read March 14, 1900.*]

While in Yarmouth, N. S., recently, I noticed a cast-iron pipe joint that is used there which is different from anything I have used or seen used in the United States.

In this joint the spigot and bell of the pipe are turned as shown in the accompanying sketch (Fig. 1).* This drawing was furnished

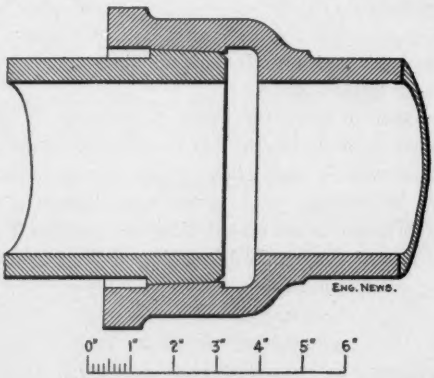

FIG. 1.

me by the Montreal Pipe and Foundry Company, which has a pipe foundry in Londonderry, N. S., where this form of pipe is made. This company informed me that the charge for this pipe was about five dollars per ton more than for the ordinary bell and spigot pipe, which would mean an addition of about thirteen per cent. to the Canadian price of pipe.

The drawing shows a 4-inch pipe with a lead space one inch deep by one fourth inch in thickness. The weight of this lead joint would be approximately 0.15 pound per foot of pipe, with 12-foot lengths, while in the ordinary pipe joint it is 0.5 pound per foot of pipe.

The following table shows that the saving in the weight of lead will not compensate for the extra cost of the pipe : —

* For this cut the JOURNAL is indebted to *Engineering News*.

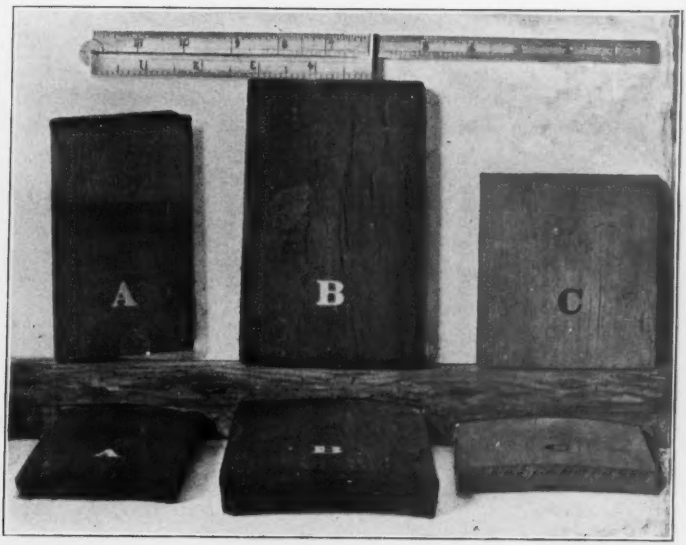

FIG. 1.

COST OF PIPE AND LEAD PER FOOT.

Diameter.	Weight per foot.	Cost, Plain Joint. Pipe.	Lead.	Total.	Cost, Turned Joint. Pipe.	Lead.	Total.	Difference in favor of plain pipe.
4 in.	18 lbs.	$0.241	$0.025	$0.266	$0.271	$0.008	$0.279	$0.013
6 "	30 "	.402	.037	.439	.455	.011	.466	.027
8 "	44 "	.59	.05	.64	.667	.014	.681	.041
10 "	60 "	.805	.055	.860	.91	.017	.927	.067
12 "	79 "	1.058	.065	1.123	1.195	.020	1.215	.092

The yarn used for gaskets is saved, as well as the time required for driving the same, by the use of the turned joint. The time usually spent in centering the pipe is also saved. The pipe, after being entered and forced home, remains rigidly in place, and there is nothing to do but run and calk the lead.

The turned portions are slushed before leaving the foundry to prevent rusting.

I am informed that ordinary deflections from line can be made as well as with the usual form of joint. It is hardly probable that as great deflections can be made as are sometimes done with the latter.

Mr. George H. Robertson, Superintendent of the Yarmouth Water Works, speaks very highly of the joint, and says that, in his opinion, the extra cost is fully offset by the ease with which the pipe is laid.

This joint certainly has an interest for water-works men.

WEIGHTS OF CAST-IRON PIPE.

The weights of cast-iron pipe adopted by different users and makers of water pipe for the same head or pressure are far from uniform. Many foundries issue cards giving their standard weights for various sizes and heads. From two cards that I have compared I have taken the following weights per 12-foot length for 200 feet head: —

Comparison of Standard Weights of Pipes from Two Foundries.— Pounds.

Diameter of pipe, in.,	4	6	8	10	12	14	16	18	20	24
First foundry	213	364	538	739	949	1232	1496	—	2128	2735
Second foundry	259	432	666	900	1196	1577	1925	2322	2744	3800
Per cent. of difference..	21.5	18.5	23.5	20.5	26.5	28	29	—	29	39

As showing the difference in the practice of engineers, the following table gives the weights of pipe used by the Boston Water Works for 200 feet head, and also those used for many years by the late M. M. Tidd, Civil Engineer: —

Table of Weights used by the Boston Water Works and by M. M. Tidd, C.E. — Pounds.

Diameter of pipe, in.,	4	6	8	10	12	14	16	18	20	24
Boston Water Works ...	260	420	600	815	1050	—	1615	—	2250	2985
M. M. Tidd.....	218	361	529	723	944	1191	1463	1761	2086	2811
Per cent. of difference..	20	13.5	13.5	12.5	11	—	10	—	8	6

Is such a divergence in practice necessary or desirable? Are those who use the light weights taking a great risk for which they must suffer in increased breakage, or are those who use the heavier weights simply throwing away money on unnecessary iron? There are probably good reasons for using heavy pipe in the business district of the city of Boston, but these reasons do not exist in most places.

This is a serious and important question for a body of men who represent the use of so much cast-iron pipe as do those who compose the membership of the New England Water Works Association to consider. How are they to decide what weight of pipe to use?

The engineer of the Metropolitan Water Board is using a list of weights for 200 feet head that are practically the same as those of M. M. Tidd, given in the foregoing table. Pipe of this weight is called by them Class C. It should be noted that in their list they do not include in Class C any pipe smaller than 12 inches in diameter. I do not know whether or not this indicates that they do not use light weights of the smaller pipe.

The following table gives the Boston weights, those of the Metropolitan Water Board, and of M. M. Tidd, for sizes from 4-inch to 24-inch and for 200 feet head: —

Table of Weights of Pipe for 200 Feet Head.

Diameter, inches.	Boston Water Works. Weight in Pounds.		Metropolitan Water Works. Weight in Pounds.		M. M. Tidd. Weight in Pounds.	
	per ft.	per length.	per ft.	per length.	per ft.	per length.
4	21.6	260	19.1	209	18.2	218
6	35	420	30.4	365	30.1	361
8	50	600	45.2	542	44.1	529
10	67.9	815	62.2	746	60.3	723
12	87.5	1050	80.7	970	78.7	944
14	—	—	100	1200	99.4	1191
16	134.5	1615	123.6	1485	122	1463
18	—	—	—	—	146.8	1761
20	187.2	2250	173.2	2080	173.8	2086
24	248.5	2985	228	2740	234	2811

As the result of my experience and observation I believe that the water pressure has little to do with the breakage of water pipe under

the ordinary conditions that prevail in water works. I omit from this statement such extreme pressures as 150 pounds per square inch and over. Aside from these unusual pressures, I am very firmly of the opinion that the pressure need not be considered in the design of the thickness of water pipes. It should be controlled by other factors. I imagine that many men who handle and lay water pipe will agree with me when I say that any pipe that will pass the test of 300 pounds water pressure imposed upon all pipes at the foundry, and stand transportation and handling until laid, will sustain the water pressure in any ordinary water-works system, no matter what their weight or thickness may be. The critical consideration is at what thickness of shell will the point be found where the saving in weight of iron will be exceeded by the loss due to breakage in transportation and handling. There is another element which should be considered, and that is the place in which the pipe is used, as affected by heavy traffic on the street surface above and the liability of disturbance by excavation in the street for other purposes; or, in other words, the difference between urban and suburban conditions.

I believe that all fine distinctions of classification of water pipe can be abandoned with safety and advantage, and three classes be adopted that will cover all cases in water-works practice: —

1. "Light" pipe, to be used with less than 100 feet head or 43 pounds pressure, or for temporary work.

2. "Standard" pipe, for all ordinary water-works service from 43 to 150 pounds pressure or 100 to 350 feet head.

3. "Heavy" pipe, for all pressures exceeding 150 pounds, and for places requiring strength to resist external stress, such as city streets.

The following table is a suggestion for the weights of such classes for pipe from 4 to 24 inches in diameter.

Table Giving Weights of Cast-iron Pipe from 4 to 24 Inches in Diameter. — Pounds.

Diameter, inches.	Light Pipe.		Standard Pipe.		Heavy Pipe.	
	Weight per ft.	Weight per length.	Weight per ft.	Weight per length.	Weight per ft.	Weight per length.
4	17	204	19	228	22	264
6	27	324	30	360	35	420
8	40	480	45	540	50	600
10	54	648	60	720	70	840
12	68	816	80	960	90	1080
14	85	1020	100	1200	115	1380
16	105	1260	125	1500	145	1740
18	120	1440	150	1800	175	2100
20	140	1680	175	2100	205	2460
24	185	2220	225	2700	270	3240

If some such system could be adopted, it would result in a great simplification of the pipe business. All pipe could be ordered and paid for by the lineal foot with the provision that they should not fall short in weight more than a certain percentage. All questions of long and short tons would be settled, and the inspector would only have to count the pieces and see that the weight marked on the pipe was not less than the minimum.

If we could go a little further and have a set of standard specifications for pipe, much time, expense, and misunderstanding would be saved.

If specifications could be prepared that would receive the sanction of this Association and be known as the New England Water Works Association specifications, they would be a valuable addition to water-works practice. Such specifications need not preclude individual ideas, for if one wished to hold to some peculiar notions of his own, and was willing to take only a fraction of the trouble that he must take at present, they could be simply added to the standard specifications for his own use.

Then an inquiry for pipe could read as follows: —

To the Bell & Spigot Foundry.

Quote prices on 5 000 feet 10-inch Standard water pipe, New England Water Works specifications, delivered in Blanktown.

Yours truly,

Pipe Line.

This would cover every point thoroughly, and could be done by wire at small expense.

Such specifications would tend to introduce uniformity in a line of work in which it is possible and most desirable.

Discussion.

Mr. John C. Chase. The use of cast-iron pipe with what is termed a turned or ground joint was common in England and Scotland some thirty years ago, but I am not aware that it has ever been used in this country. When the Manchester, N. H., Water Works were built in 1872, the force main, which was to be of cement-lined wrought-iron pipe, was provided with cast-iron bells and spigots, and an attempt was made to use a ground joint. No lead was to be used in the joint; but the experiment was not a success and a regular lead joint was substituted. It may be a novelty to some who do not

know about it to be told that the sheet-iron shell was put into the mold, and the cast-iron bell and spigot cast around it. What condition it is in at the present time I do not know, but perhaps our friend Walker can tell us.

MR. CHARLES K. WALKER. It has worked well so far.

MR. CHASE. This is the only case I am aware of where pipe of that description has been used. As I remember it, it was on the lower third of the force main, where there was something like one hundred feet pressure.

MR. COFFIN. I omitted to state that this pipe of which I spoke in the paper was originally introduced into the Provinces from Scotland. It is termed a turned joint and not a ground one, and is not intended to be tight, but only to do away with the gasket and to center the pipe.

MR. CHASE. I believe the original Scotch pipe dispensed with the lead entirely. Is not that your understanding?

MR. COFFIN. That may be true; but the information I received was that this particular pipe was brought first from Scotland and then copied in the Londonderry foundry.

MR. CHASE. In the case I have mentioned it was proposed to dispense entirely with lead, using instead a turned joint, and have the pipes driven together tightly enough to prevent leakage; but the experiment was not a success.

CEMENT-LINED SERVICE PIPES.

BY FAYETTE F. FORBES, C. E., SUPERINTENDENT, BROOKLINE, MASS., WATER WORKS.

[*Read February 14, 1900.*]

Of the many problems which confront those who design and maintain systems of water works, perhaps no one is more perplexing than that of selecting the right material for service pipes.

The choice must lie between some kind of protected iron and lead, for plain wrought-iron pipes are completely stopped up in a few years by the formation of rust, and the water which is drawn through them from the first is more or less discolored and thereby rendered unfit for laundry or other domestic purposes.

There are several ways of attempting to protect the wrought-iron pipes from the oxygen in the water; but with the exception of a lining of lead, tin, or cement, the processes have a doubtful value in prolonging the life of the pipes for the purposes for which they were designed, beyond a few years.

It seems to the writer that, with our present knowledge, it is not wise to use lead in the great majority of cases for several reasons, although it has the advantage of being easily carried over, under, and around obstructions, and resists the corrosive action of some soils much better than wrought iron. It is well to bear in mind in this connection, however, that the water supplied any city or town may change with varied conditions, or perhaps it may be necessary to obtain a supply from an entirely new source, and the new water may attack the lead freely and thereby cause an injury to the health of the people using it.

An experience of twenty-six years has convinced the writer that cement-lined wrought-iron pipe can be made, and the lengths put together in such a way that a very excellent service pipe is obtained.

Pipes have been removed during the past year in the Brookline plant which have been in use for twenty-five years, and no accumulation of rust was found on the inside of them, and the water way was as clean and perfect as the day the pipe was laid; and moreover several have been removed during the past years and all tell the

same story. I might state further that for twenty-five years not one cement-lined pipe used in Brookline has failed to deliver its supposed quantity of water, when demands have been made on it, and in addition to this continuous freedom of flow, the water is always free from rust unless some disturbance has occurred in the street mains, for which, of course, the service pipes are not responsible.

I do not believe that the conditions in Brookline differ greatly from the conditions in most other cities and towns, and I must think that our success with cement-lined service pipe is owing in a large measure to the care taken and skill employed in lining it.

From an economical point of view, a pipe of this kind takes first rank. The total cost of preparing and lining a one-inch pipe, including cement, never exceeds one and one-half cents per foot. Last year the total cost of one-inch pipe lined and piled up, was four and two-tenths cents per foot. This year, however, owing to the great advance in the price of iron, it will be about eight and two-tenths cents per foot.

This cost is given at this time that a comparison may be made to-day with a three-quarter wrought-iron pipe differently protected from rust, which gives about the same capacity when new as a one-inch cement-lined pipe.

Cost of	$\frac{3}{4}$	-inch	tin-lined	pipe is about	$0.325
,, ,,	$\frac{3}{4}$	,,	,, ,, lead	,, ,, ,,	.48
,, ,,	$\frac{3}{4}$	,,	lead-lined	,, ,, ,,	.13
,, ,,	$\frac{3}{4}$	,,	enameled	,, ,, ,,	.11
,, ,,	$\frac{3}{4}$	,,	galvanized	,, ,, ,,	.08
,, ,,	1	,,	tarred	,, ,, ,,	.066
,, ,,	1	,,	cement-lined	,, ,, ,,	.082
,, ,,	$\frac{3}{4}$	,,	lead	,, ,, ,,	.225

It seems to me that a description of the whole process of lining may be of interest to the members of the Association, and I will state it as briefly as possible. Our manner of procedure is as follows: —

PIPES.

Our departure from the usual custom begins with the buying; we specify that the lengths shall be about sixteen feet long and also of standard weight. A pipe eighteen or twenty feet long cannot be lined with the same degree of success which can be obtained with pipes somewhat shorter; and our experience has taught us that pipes

about sixteen feet long give the best results. I might add that we find no difficulty in buying pipe of the shorter lengths, and neither is the cost increased thereby.

After the pipes are delivered at our shop, we first straighten all which are much bent. The couplings are then removed, turned around, and screwed on the other end, in order that there may be no trouble in putting the lengths together when lined. The pipes are then carefully examined in order to make sure that no defect exists in the welds or other parts of them. The next step is to run a cutting tool slightly smaller than the inside diameter of the pipe through each length to remove all dirt, scales, and projections of iron from the welds. The pipes are now ready for lining.

LINING.

No sand should be mixed with the cement. Portland cement is not fit for this work, being too heavy and liable to fall from the sides of the pipes before setting. We have used the F. O. Norton brand with great success; but any good American natural cement, which does not set too rapidly and is freshly ground, can be used with confidence. It is very necessary to sift all the cement through a moderately fine sieve, as we find that even the best cements contain small pieces of unground rock and other substances which interfere seriously with the lining. It is also extremely important that the cement should be used quickly after wetting.

When lining, we have one man who does nothing but mix the cement, usually preparing enough for five or six pipes at one time, and constantly working it over to keep it at the right thickness. If a little of a batch is left, we prefer to throw it away rather than to mix it with the next lot.

The press used for filling the pipe is made by the Union Water Meter Company, of Worcester, Mass.; in fact, they make the whole outfit, including cones, etc. It is necessary to fill the pipe entirely full of cement, and a little should be allowed to run out of the farther end. More of the cement will be pushed out by the cones, but this can be returned to the mixing-box and used again, with the exception of that from the last pipe filled from the batch, which is thrown away.

In every case the cones are passed through the pipes twice. A handful of cement is pushed into the pipe before the cone enters the second time; and while it is being drawn through, the pipe is slowly

revolved to keep the cone in the center of the pipe. We endeavor to keep the cones as near the center of the pipe as possible; we find, however, that the practical results are the same if the lining is quite uneven.

The cones are thoroughly washed after each pipe is lined; before they are drawn through, a piece of pipe from twelve to eighteen inches long is screwed to each end of the pipe to be lined, so that the lining at the end will be perfect.

After the pipes have been lined from three to five days, or until the cement has sufficiently set, a thin gruel of cement is run through them. This is done by elevating one end of the pipe and pouring the gruel in from an ordinary watering pot. A rubber cone is now drawn through, which leaves the inside of the pipe smooth and quite impervious to water. The ends are now reamed out to fit the composition ferrules and the threads cleaned. This completes the process, and the pipes are piled away for use.

The number of feet of pipe of different sizes, lined and grouted by one barrel of cement, is as follows: —

1 inch pipe, 700 feet.
1¼ ,, pipe, 500 ,,
2 ,, pipe, 300 ,,

COST.

In 1898, the cost of labor, cement, etc., for lining 3 000 feet of two-inch pipe and 9 000 feet of one-inch pipe was as follows: —

Labor, preparing pipes	$65.79	
,, cementing	66.65	
,, grouting	22.66	
,, reaming	39.98	
23 barrels cement @ $1.10	25.30	
Coal for heating shop	6.00	$226.38

Which gives the cost of lining two-inch pipe 3.03 cents per foot, and cost of lining one-inch pipe 1.5 cents per foot.

NUMBER OF MEN REQUIRED.

Two men usually get the pipe ready for lining, but during the process of lining, six men are found to be the most economical number to use, distributed as follows: one man mixing the cement, one

man filling the press and overseeing the work, one man working the press, one carrying the pipes to the press and from the press to the coning-frames, and two men, one at each end of the pipe, doing the coning.

In one day, these men will line from four to five thousand feet of pipe.

JOINTS.

A few words describing the ferrules we use at all joints; these are made of the best steam metal, five-eighths of an inch in diameter on the inside, the outside tapering slightly towards the end. They are of two kinds, called by us a double and a single ferrule. The double ferrules are used where the pipes are screwed together, and the single ferrules where the pipes are screwed into the sidewalk stops and connections at the main, which are made with a shoulder at the end of the thread to hold the ferrules in place.

When the service pipes are laid in this way, no unprotected iron exists anywhere on the whole inside, and we feel that we have a pipe which will give as good a water in the house as runs in the street mains outside.

BENDING.

It has often been stated that the cement-lined pipe cannot be bent without injury. We find, however, that the pipes can be bent to any reasonable extent, without any damage to the lining, if this is done with care.

Discussion.

Mr. Charles W. Sherman.* When Mr. Forbes speaks of two-inch pipe and one-inch pipe, does he mean the diameter before lining or after?

Mr. Forbes. When I speak of two-inch pipe and one-inch pipe, cement-lined, I mean what is commonly called two-inch pipe and one-inch pipe. In lining an inch pipe the bore is reduced to about three-quarters of an inch, and a two-inch cement-lined pipe is about an inch and seven-eighths in diameter. It lessens the diameter a little less than a quarter of an inch. We use an inch pipe where they ordinarily would use a three-quarter wrought-iron or three-quarter tin-lined or lead-lined pipe. The price I have given here, you

* Assistant Engineer, Metropolitan Water Works.

understand, is for an inch pipe in comparison with three-quarter lead, and three-quarter wrought iron.

MR. FRANK L. FULLER.* I would like to ask Mr. Forbes when he puts this double ferrule in, where he joins two pieces of pipe together, whether there is any cement put in, or whether it is just slipped in and allowed to fit as it will after it has been reamed out.

MR. FORBES. For a great many years we have used nothing. We did use cement at one time, but we find the ferrule packs in so solidly that before the rust from the end of the pipe can get to the end of the ferrule it has made a complete dam for itself. It is in very tight, anyway, the reamer being but a very little larger than the outside of the ferrule; we have to drive it in, and I have never found the rust quite to the end of the ferrule.

MR. FULLER. Is there any trouble in screwing up the pipe? Does that jam the ferrule into the old cement in the pipe and fracture it at all? Have you had any trouble from that?

MR. FORBES. No; we have n't had any trouble in that way.

MR. FULLER. Mr. Billings, of Taunton, devised a scheme, filling his couplings with lead, and putting in a German silver ferrule, which was aimed to accomplish this same result. I presume that it may have been described in our papers. It does not seem to me, however, that it is as cheap or as well fitted for the purpose as the one Mr. Forbes has described. As connection was made, the little German silver ferrule slipped inside of the cement; but if the cement lining was n't exactly concentric with the pipe, that is, if the thickness was not exactly the same on each side, the ferrule was very liable to get bent up, and to fail to accomplish the result aimed at.

MR. T. H. MCKENZIE. I would like to inquire of Mr. Forbes whether any concern makes this pipe and puts it on the market, or whether every man must line his own pipe.

MR. FORBES. I don't know of any one who has it for sale, although there may be some one who does. You need to use great care all the way through the process of lining, particularly, to keep everything clean. When we first began to line, years ago, we did n't look over our pipes, and every now and then we would find pieces of iron in them, which prevented the cone passing through, and consequently, the cement mixed up would spoil, and time was lost. Now we have everything all right before we begin. Sometimes the couplings are jammed, but by taking the coupling off the end of one

* Civil Engineer, Boston, Mass.

pipe and turning it around and putting it on the end of another one, we are sure that the thread on the pipe is all right, and the thread in the coupling also. We at first cemented our pipes without sifting the cement. And you will be surprised, with our best cement, even, how many little unground pieces of rock you will find, and there is also more or less paper and more or less wood which comes from the barrel; and we find that by sifting the cement it works very much better. If we don't do that, little pieces of stone or wood are liable to get on one side of the pipe, and may make the lining very uneven, or perhaps take it all off on one side of the pipe.

MR. MCKENZIE. How would the price of a one-inch cement-lined pipe compare with the price of a three-quarter inch unlined pipe?

MR. FORBES. These prices, of course, are only for the sake of comparison, because they vary from year to year and almost from day to day. A galvanized pipe to-day will cost about eight cents a foot with the best discount I can get, which is fifty, ten and five per cent. from the list. An inch pipe, with the same discount, cement-lined, will cost to-day 8.2 cents a foot; that is the price of the pipe and the cost of lining, including the cement. In other words, it would cost two-tenths of a cent per foot more than galvanized pipe, one costing 8 and the other 8.2 cents.

MR. MCKENZIE. A one-inch galvanized pipe before it is lined costs 8.2 cents?

MR. FORBES. No, we don't line galvanized iron pipe; we line plain pipe. A three-quarter inch galvanized pipe to-day would cost about 8 cents a foot, and a one-inch plain pipe lined would be 8.2 cents to-day. The cost is in effect less than it appears, for this reason: we do most of this work through the winter, with the same men we employ to look after the hydrants, and other things connected with the maintenance of the work. When we have a cold spell they are on the hydrants, and when we have a mild spell we put them to work preparing this pipe.

MR. SHERMAN. I would like to ask Mr. Forbes whether he has ever noticed any difference in the frictional resistance; if it is appreciable between the flow through a cement-lined pipe and an ordinary wrought-iron or lead pipe.

MR. FORBES. I have n't made any experiments in that line, but if you examine the inside of these pipes you will find they are always smooth. Take any kind of enameled pipe that I have ever seen, or galvanized pipe or tarred pipe, and after a few years you will find

a great many little bunches of rust along on the inside, which must interfere with the flow. A cement-lined pipe being always smooth, of course offers no more resistance, practically, than a lead pipe.

Mr. Sherman. Another question relates to a trouble which may not occur in Brookline on account of the character of the water; but as far as I have been able to notice whenever a cast-iron pipe is cut in Boston we find a slimy growth of polyzoa on the interior of the pipe; and I would like to know whether that has been noticed in the cement pipe.

Mr. Forbes. I have never noticed it, and in fact I have never noticed a growth of that kind in Brookline any way; because our water, coming as it does from wells and stored in a covered reservoir, does n't contain anything for them to live on.

Mr. Fuller. I would like to ask Mr. Forbes if he makes any protection at elbows and T's in this way.

Mr. Forbes. We rarely use any elbows or T's. If we have to use a turn smaller than we think best to bend the pipe around we use a short piece of lead pipe, perhaps a foot long, with a coupling on the end like that I passed around, and in making the connection we use ferrules.

Mr. Fuller. Is this cement pipe used much in houses?

Mr. Forbes. No; it is n't used very much inside. In fact, we don't sell this pipe to private parties, except where we lay it in the ground. It is n't on the market. It is rather clumsy to lay inside when you cut joints.

Mr. Fuller. What is used inside mostly, — lead?

Mr. Forbes. We use a great deal of iron pipe in Brookline, and some lead for hot water.

Mr. George F. Chace.* I should like to ask Mr. Forbes how many complaints he has during the year of poor service, — that people can't get a full supply of water.

Mr. Forbes. We never have any on cement-lined pipe.

Mr. Chace. Cement-lined pipe has been used in Taunton since 1876, and during the past year we had 119 such complaints, — cases where we had to take the pipe out. Now, I agree with Mr. Forbes that it is perfectly feasible to line the pipe, and there is no special difficulty about bending the pipe. We can make a cement-lined pipe a good deal better than the specimen shown here, and Mr. Forbes says he can now. The trouble we have is largely in the fittings.

* Superintendent, Taunton Water Works.

Some gentleman, a little while ago, alluded to certain fittings designed by Mr. Billings. I can say they are a complete failure, because I have taken out one of those couplings and examined it, where the thimble or ferrule had been put inside, and the nickel plating of the brass ferrule had come off, and the coupling was half full of rust, where the water had got at the iron, somehow. That was a complete failure, and we have stopped using it, and gone back to a plain coupling. This which has been exhibited here this afternoon may be better than that; but I measured one of these ferrules just now and found it was only a half an inch capacity at the end, and that is reducing the opportunity for a full flow of water, it seems to me.

MR. FORBES. That is about the same diameter as the inside of the corporation cock is supposed to be. And one reason why I adopted that composition ferrule was, that we never have a corporation cock or a sidewalk stop filled with rust, except where an iron pipe is screwed into it; and I thought if our corporation cocks and our sidewalk stops were rust proof, the same metal would work equally as well when placed in a coupling, and I have found that it does. I know that various kinds of ferrules of tin and lead have not proved successful; and I think one reason for that may be that they are rather weak, and when you screw them together they become bent in revolving the pipe. That is, the cement lining may not be quite in the center of the pipe, and when you turn the pipe around, a lead ferrule may be bent out of shape, and the rust may get in back of it and eat its way in. But our couplings, which are of just the same kind of metal as the sidewalk stops and corporation cocks, have given us very good service.

MR. H. G. HOLDEN.* I would like to inquire what kind of pipe is in general use in Brookline for inside work.

MR. FORBES. They usually run an iron pipe to the sink, very often enameled pipe, and in some few cases galvanized pipe, and in some cases tarred pipe.

MR. HOLDEN. Do you have any trouble?

MR. FORBES. We do. We have to take them out quite often, but they are where we can get at them quickly and it can be done easily. I suppose in a house piped twenty-five years ago all the iron pipe has now been removed. They usually run lead from the kitchen up to the bath room.

* Superintendent, Nashua Water Works.

MR. GEORGE A. STACY.* I would like to ask Mr. Forbes if he protects the outside of his pipe with anything.

MR. FORBES. No; I used to give them a bath of tar years ago, but I have given that up now. We all know, or at least we find it so in Brookline, that a wrought-iron gas pipe will very rarely rust through from the outside. You will find them in the ground without leaking after years and years and years. This sample which I have passed around, you will notice is covered with a coating of dirt and iron oxide, which forms around the pipe and seems to protect it. And I have reasoned that if a gas pipe would stand for years without rusting through from the outside, a water pipe would stand as long, and so far we have had no trouble at all.

MR. CHACE. That reminds me that my foreman showed me yesterday a piece of pipe, just about as long as the piece exhibited here, and the coating of cement on the inside was perfect, but the outside of the pipe was half gone.

MR. GEORGE E. WINSLOW.† Are you troubled with electrolysis there?

MR. CHACE. I don't think so.

MR. STACY. We have used cement-lined pipe for a number of years, and have a number of miles of it in now, and my greatest trouble from it has been from the iron rusting out. There has been no trouble with the cement, and I don't know why there should be, for that is as durable as rock itself. We thought first of grouting it, but after a while we thought that did n't do any great good. In handling the pipe it is bent more or less, unless you are very careful; and then, in laying it in the trench, in a place like our city, we have to go around a number of obstructions; there are a good many bowlders and rocks, and one thing and another, and we have to have a good many bends. I can't conceive how you can bend a cement-lined pipe without fracturing the lining. The cement won't come off, because it is arched and locked in there, and it is almost impossible to take it out without destroying the pipe; but at the same time you will fracture the cement, unless you have a cement which is elastic, which is a thing I never saw. My experience has been that you have got to handle a two-inch pipe a little more carefully than you have an inch pipe on account of the larger arc of the pipe. I can conceive that if you should put an eighth of an inch of

* Superintendent, Marlborough Water Works.

† Waltham, Mass.

cement into an eight-inch pipe, the arch would n't be enough to lock it so it would n't drop out; but it is almost impossible to knock the cement out of a three-quarter inch pipe without destroying the pipe.

We have used lead pipe inside the houses for our best plumbing for years, and, as far as I know, we have never had any bad effects from it. If you can get a cement-lined pipe which will stay where you put it and stay there forever, as Mr. Forbes seems to think, and you can use no other kind of pipe with perfect safety, it seems to me you have no choice in the matter. I don't know of any coating that you can put on the outside of a wrought-iron pipe that will thoroughly protect it. Of course there is great difference in soils, and I should judge the soil in Brookline was very favorable for the laying of wrought-iron pipe. There are lots of places in my city, however, where iron pipes that have n't been laid over fourteen years have rusted out completely. And while a pipe might hold gas, it does n't follow that it would hold water, because the water is of course under a good deal more pressure. I have had to abandon cement-lined pipe for the reason that we have not yet been able to find anything to protect the outside of it. A cement-lined pipe is certainly the cleanest thing we can use. I suppose the ideal pipe would be glass, if it could only be made so we could handle it. But, as I say, my trouble has been with the iron giving out, and not with the cement. The cement we find just as good as it was at the time the pipe was put down, but the iron won't stand in our soil in a good many places. We have taken some out which have been in good condition, while others, which have been perhaps in the same street, have been completely gone.

Mr. Forbes. I might say that there is a good deal of pipe on the market that is light weight. Of course they don't say anything about the weight, and unless you specify that the pipe must be of standard weight you will be very apt to get it light. We buy at the mills and have it shipped to us by the carload. If you buy it out of stock, it is likely to be made of poor iron, and it won't stand the effect of rust as it ought to.

A Member. I would like to have Mr. Forbes inform us, if he will, how he makes his connections with the street mains, — whether he puts the pipe directly into the corporation cock, or whether he uses a lead connection between the cement-lined pipe and the main.

Mr. Forbes. We use a piece of lead pipe, twelve or thirteen inches long, with a coupling soldered on.

MR. WINSLOW. Mr. Forbes says that iron pipes are light weight, and I have found that not only true of iron, but of steel. I think perhaps the difference in the metal has considerable to do with the way both iron and steel pipe will stand in different soils. I have generally found iron pipe of standard weight, and have never had any trouble in getting it when I have asked for it; but steel pipe is usually very thin, and I think perhaps it is of such a nature that it shows the action of the soil quicker than iron does.

MR. E. A. W. HAMMETT.* One question has been asked here which I have not heard any answer given to yet, and I am not sure that I can say anything on the subject which will be of special interest. The question was asked by one of the gentlemen whether cement-lined pipe was used in houses. I would say that I know of at least one case where it has been used, and that is in my own house. When, some years ago, I was living in Newton, we put in at first tarred pipe, and within four years' time it became so plugged up with rust that we could n't get any water through it. We then took out all the pipe from the street to the house, about one hundred and sixty feet, and a portion of the piping in the house, and replaced it with an inch pipe, lined with cement. That was about sixteen years ago, and at that time I knew nothing whatever about a ferrule in making connections, so we used simply the ordinary fittings with no lining. But I have had no trouble whatever, since we put in the new pipe, in getting a full supply of water, and have seen no signs of rust in the faucets. We use a cement-lined pipe up to the kitchen sink.

MR. EDWIN C. BROOKS.† I would say that the principal trouble we have is the stopping up of the corporation cocks in the mains. What we call rust is really a form of tuberculation which takes place over the opening into the corporation cock, and we have more trouble with that than we have with the supply pipes. But, after all, it seems to me that the whole question resolves itself into the question of the character of the water. With Fresh Pond water, as it was formerly supplied to Cambridge, the supply pipes would last and remain clean for years, as the water was hard, and very slight tuberculation took place. But since the introduction of Stony Brook water, which is very much softer, we get a very much more rapid growth of tubercles, and we find sometimes on removing the cor-

* Civil Engineer, Boston, Mass.
† Superintendent, Cambridge Water Works.

poration cocks from the mains that they are filled over solid, almost, so that there will be only perhaps a hole as large as an ordinary straw leading to the cock. And I have known numerous cases where a family has been supplied with water, without any complaint whatever, where the hole through this formation of tubercles has not been more than a quarter of an inch in diameter.

MR. CHACE. Mr. Forbes says he has never been troubled with pieces of cement getting into the meters. It is not an uncommon thing for us to find pieces of cement in the meters. I suppose he, as well as all the rest of us, is obliged to cut his service pipes once in a while, and I should think it would be almost impossible that there should not be some crumbling of the cement when you cut the pipe, and probably the particles that we have found have come from such places as those. That is one obvious objection there may be to the use of cement lining, if we could find anything better.

MR. R. J. THOMAS.* I will state that recently I had occasion to go around and visit a number of superintendents, trying to get some ideas about service pipe, and I found that there was quite a difference of opinion among them. In fact, my inquiries left me in doubt as to whether there had yet been devised any kind of a pipe which was fit to conduct water. I waited on Mr. Forbes, who, I think, has given the matter very careful attention, and was very much impressed with the way in which he lined his pipe, and I have no doubt that he has been entirely successful with it. On the other hand, other superintendents found a good deal of fault with cement-lined pipe. I also found quite a strong objection to the use of lead pipe, especially five-eighths and half-inch sizes. I was told that it not infrequently filled up with vegetable growths, or sediment of some kind. And I also found that some superintendents had had a good deal of difficulty with the goosenecks or lead connections of the iron pipe filling up with sediment. It seemed to be the general result of experience that a five-eighths or half-inch lead pipe, and in some cases a three-quarter inch, had not worked well in use. I think the Association ought to appreciate the very courteous manner in which Mr. Forbes has answered all our questions, and that he deserves our thanks.

MR. CHACE. Have any of the members present had any experience in using tin-lined pipe?

MR. WINSLOW. I know of a tin-lined pipe which was put in in 1873, and it is still in use.

*Superintendent, Lowell Water Works.

MR. JOHN C. HASKELL.* Mr. Chace himself has had some experience with tin-lined pipe, and perhaps he will tell us about it.

MR. CHACE. We have been using it five or six years, and I don't see any reason to change. I am perfectly well satisfied with it, except that it costs too much.

PRESIDENT BYRON I. COOK.† I presume, gentlemen, this question resolves itself right down into each one of us using the pipe which fits his own case best, and it is a matter of experiment to tell which is best for any particular locality. I think myself that, with a surface water supply, lead pipe under ordinary conditions will prove as satisfactory as any. In regard to trouble with stoppage at the main, I have experienced some of that myself, and the way I get over it is by having the corporation go through the cast-iron pipe at least a half to three-quarters of an inch. I have never had any trouble from a corporation sealing over with tubercles when it went through the main that far, but when it has been flush on the inside I have. I have found one completely stopped and another within ten or fifteen feet of it would be completely open. I think the experiments which have been conducted by the Massachusetts State Board of Health in regard to lead poisoning have demonstrated that for ground water supplies some other kind of pipe than lead should be used for the services. If Mr. Forbes has solved this problem, which Mr. Chace rather doubts, apparently, then Mr. Forbes is of course satisfied, and Mr. Chace is still open to conviction as to what is the best for him to use.

MR. FULLER. I don't know whether Mr. Forbes has told us how long he has used these ferrules. He has spoken about using the pipe for twenty-five years or more, and I would like to ask him how long he has used this particular form of ferrule in his connections.

MR. FORBES. The very first pipes we laid did n't have any ferrules, but I believe we have used these now, probably, in the neighborhood of eighteen years. I don't know of any other place where there is a ferrule like this used, and we had our own patterns made. I might say that I think this year the single ferrule costs about three cents apiece and the double ones about four and a half cents apiece. Of course they are a great deal higher now than they were last year, on account of the higher price of copper composition.

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* Superintendent, Lynn Water Works.

† Superintendent, Woonsocket Water Works.

A VERY BRIEF DISCUSSION OF LEAD POISONING, CAUSED BY WATER WHICH HAS BEEN DRAWN THROUGH LEAD SERVICE PIPE.

BY FAYETTE F. FORBES, C. E., SUPERINTENDENT, BROOKLINE, MASS., WATER WORKS.

[*Read February 14, 1900.*]

Of course it is understood that the writer is not a chemist, and in this brief discussion, the information which he has comes from a study of the work done by those who are competent and have the facilities to make investigations in this direction, and I say these few words in this connection simply to give expression to some of the thoughts which these studies have suggested to me, in hopes that these suggestions may bring the subject more vividly to the attention of the members of this Association, and thereby cause more consideration to be given to it. In the first place, I would ask all interested in this matter to carefully read the Report of the Massachusetts State Board of Health for the year 1898. I do not know any other volume which will give so much up-to-date, practical knowledge on this subject. Allow me to quote from page 32 of this report, that the importance of the subject may be better understood: "It has been found that many waters, when brought into contact with lead service pipes, as in lead distribution pipes, dissolve lead from the pipes, and the water thus becomes dangerous to those who drink it. While the quantity of lead dissolved may be small, and a single dose might not harm the user of the water, the continued use of water containing lead is harmful, because lead is a cumulative poison. The exact amount of lead which may be taken into the system without producing harm is not definitely known, and may vary in different people; but it is known that the continued use of water containing quantities of lead as small as .05 of a part per 100 000 or about $\frac{1}{33}$ of a grain per gallon, has caused serious injury to the health."

By an examination of the several tables which are given in this report, it will be seen that the water in many cities and towns which is drawn through lead service pipes contains a much larger amount

of lead than .05 parts in 100 000, and it is a fact well established in this report that lead poisoning of quite a serious nature has occurred in this state from the use of water drawn through lead service pipes.

The investigation of the State Board of Health has also shown that a change in the source of supply — that is, furnishing a different water through the same lead pipes — may make the use of water dangerous to health where no danger existed before, on account of a much larger amount of lead now dissolved.

It is found that there are many things which contribute to increase or decrease the amount of lead which a water may take up.

I should like again to quote from this report; we read on page 563 as follows: "A review of results of all experiments indicates strongly that the two active agents in the waters, causing them to take lead into solution, were oxygen and carbonic acid. The purer the water (for instance, distilled water), the more active these agents were upon lead when in this water. The presence of nitrates and ammonia in distilled water, together with free access of air, caused a very violent action upon the lead to take place; but they had much less influence when present in natural waters containing some organic matter."

On page 566 it reads as follows: "A study of this table shows that the clear and practically colorless supplies, which most actively attack lead, are those containing the most carbonic acid and a small or a medium amount of mineral matter, as shown by the determination of hardness." On page 568, we find the following: "Again, it was shown by our experiments that highly colored water would attack lead, if sufficient time and air were allowed for the change of the carbonaceous coloring matter to carbonic acid in the presence of oxygen. This change probably occurs when some highly colored surface waters remain in the service pipes for some hours." The report goes on to say, farther down on the same page: "In —— we have a marked example of a water which, while not acting so violently upon lead that much is taken from the pipes when the water is drawn frequently, still is of such a character that, when allowed to remain for a considerable period of time in the pipes, it takes considerable lead both in solution and suspension from them; that is, a coating of organic and mineral matter forms upon the pipes, carbonic acid is generated, which, together with the oxygen present, attacks the lead, and this deposit is, when the water is drawn quickly after hours of rest, apparently easily detached from the pipe and drawn out, thus increasing the amount of lead in water

drawn after periods of rest above that actually taken into solution by the water during this period of rest."

These quotations show the many causes which make it possible for water to dissolve lead, and should teach us to look with extreme caution to the use of lead for service pipes. It is also quite a serious matter, from a financial standpoint, to invest thousands of dollars in lead pipe, and then find that we have an element of serious danger in our midst which, sooner or later, must be remedied. The health of a community must first be considered; this goes without saying.

Now, in the light of so much conclusive evidence which is within our reach, what position should we take in this matter in constructing and maintaining a system of water works? Is it not wiser and better to eliminate all possible elements of danger from a thing so vital as the water which we must daily take into our bodies? We must bear this fact in mind: that ordinary citizens know little about these things, and trust to those who have charge of the water supplies to furnish them with a good and safe water, and we should not be unmindful of the confidence placed in us. I hope this brief discussion will draw more attention to this very important subject, and that we all shall realize the responsibilities which we have assumed.

Discussion.

Mr. H. W. Clark.* Mr. President, on this subject of lead poisoning, I should like to say just a few words. It is not a new subject at all. The fact that lead would poison the human system has been known for a great many years. Galen, who was a very famous physician in the second century of the Christian era, described lead poisoning very thoroughly, and stated that water would affect lead pipes or lead conduits, and that water taken into the city through them was harmful. Then again, Vitruvius, who was an architect in the time of Cæsar Augustus, forbade the use of lead pipes in connection with water supplies.

Coming down to rather more modern times, however, we find that there have been a good many epidemics of lead poisoning, not only the few referred to in the Report of the State Board of Health of Massachusetts of 1898, but a good many abroad. For instance, there is a well-known case of the city of Dessau, in Saxony, where

*Chemist, Massachusetts State Board of Health.

they had an epidemic of lead poisoning in 1885 or 1886. They got over it, that is, prevented the continuance of the action of the water upon the pipes by hardening the water, adding a certain percentage of carbonate of lime, increasing the hardness about sixty per cent. Then in Sheffield, England, they had a large epidemic of lead poisoning some years ago, and there they afterwards passed the water through filters of limestone and silicates, hardening the water from sixty to one hundred per cent., and thus preventing, more or less, the water from attacking the lead.

Then, in certain places in England they have, for this purpose, passed the water through towers of coke, and afterwards through filters of limestone, with the same effect of hardening the water.

In one or two places they have tried softening the water; that is, recognizing, probably, that it was the carbonic acid that attacked the pipes, they have added milk of lime to absorb the carbonic acid, which has caused a precipitation of some of the sulphates and carbonates in the water; and in this manner, after filtration, the water has been passed into the pipes with some beneficial effect.

Then in one or two places they have tried coating the pipes with sulphide of lead. But in all these various places where they have adopted different methods of changing the character of the water supply to prevent its attacking the lead, I think they have not been particularly successful, except where they have hardened the water, as in Dessau, Sheffield, and Keighley, and there may be one or two other places.

But this is not a new subject, by any means, as I have said, and people will go on using lead pipes right along, because there are many supplies, even in Massachusetts, the water from which does not attack lead seriously. But there are a good many more in connection with which we are pretty sure lead should not be used.

A Member. I would like to ask Mr. Clark if galvanized iron pipe can be used with safety where lead pipes are found dangerous.

Mr. Clark. In such cases the zinc galvanizing of these iron pipes is attacked, of course, or at least as far as our experience has gone, similarly with the lead, until a great deal of it is taken off. There seems to be left for a long period a very thin coating of zinc, and, so far as we know, zinc is not a particularly poisonous element when taken into the system. It may have some effect, but not a great deal.

Mr. Thomas. I would like to ask Mr. Clark if he knows or has

heard of any carbonate or sulphate which can be applied to water which will protect it from the action of lead and yet not harden the water.

MR. CLARK. I don't really know of any that would. I think, perhaps, sodium carbonate would; it is used for softening waters, but I do not see why sodium carbonate should satisfactorily prevent action upon lead. I have made a great many laboratory experiments with various chemicals, and have been successful in preventing action only when the water is hardened.

PROCEEDINGS.

ANNUAL MEETING.

ASSOCIATION ROOMS, TREMONT TEMPLE,
BOSTON, June 13, 1900.

President Cook in the chair.

The following members and guests were present: —

ACTIVE MEMBERS.

Francis E. Appleton, Wm. E. Badger, E. W. Bailey, Lewis M. Bancroft, Joseph E. Beals, James W. Blackmer, 2d; Dexter Brackett, Fred Brooks, George A. P. Buckman, James Burnie, George Cassell, G. L. Chapin, Byron I. Cook, J. W. Crawford, George E. Crowell, D. W. Cole, Francis W. Dean, William T. Dotten, Eben R. Dyer, F. F. Forbes, Wm. E. Foss, H. F. Gibbs, J. F. Gleason, Albert S. Glover, Amos A. Gould, Frederick W. Gow, James W. Graham, Frank E. Hall, Allen Hazen, Horace G. Holden, John L. Howard, Willard Kent, Frank E. Merrill, Leonard Metcalf, Thomas Naylor, J. B. Putnam, Charles E. Riley, W. W. Robertson, Thomas H. Rogers, W. J. Sando, Walter H. Sears, Charles W. Sherman, Sidney Smith, George A. Stacy, Frederic P. Stearns, Wm. F. Sullivan, Joseph G. Tenney, Robert J. Thomas, D. N. Tower, George W. Travis, William W. Wade, Charles K. Walker, George E. Wilde, Frederic I. Winslow, E. T. Wiswall.

ASSOCIATE MEMBERS.

Ashton Valve Co., by C. W. Houghton; Coffin Valve Co., by F. E. Adams and H. L. Weston; Mellen S. Harlow; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin; Perrin, Seamans & Co., by Harold L. Bond; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by F. N. Connet; Sumner & Goodwin Co., by Frank E. Hall; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by A. S. Otis; Walworth Mfg. Co., by B. F. Polsey; R. D. Wood & Co., by E. F. Krewson; Hersey Mfg. Co., by Albert S. Glover.

GUESTS.

F. C. Cook, Somerville; Hon. S. P. Tenney, Chairman Water Commissioners, Chelsea, Mass.; Edward M. Shedd, Inspector, Somerville, Mass.; Wm. P. Jones and E. B. Pense, Editor and City Editor *Somerville Journal*, Somerville, Mass.; George E. Borden, Fall River, Mass.; M. J. Dowd, Commissioner, Lowell, Mass.; W. C. Morgan and F. E. Hunter, Beverly, Mass.; S. M. Spencer, Boston, Mass.; C. B. Crowell, Brattleboro, Mass.;

E. F. Knowlton, Commissioner Public Works, Quincy, Mass.; Charles H. Sargent, Newburyport, Mass.; George T. Staples, Dedham, Mass.

The following new members were elected: —

Resident Active.—E. R. Payson, Secretary Portland Water Works Co., Portland, Me.; Henry Souther, Member Board of Water Commissioners, Hartford, Conn.; Norman A. McMillan, Superintendent Billerica Water Works, North Billerica, Mass.

Non-Resident Active. — Myron E. Evans, Civil Engineer, New York City.

Associate. — Sweet & Doyle, Selling Agents The Vincent Valve, Cohoes, N. Y.

On motion it was voted that a committee to nominate candidates for the offices to be filled at the annual election be appointed by the chair. The president stated that he would announce his appointments at a later time. Subsequently the membership of the committee was announced as follows: J. C. Whitney, P. Kieran, Charles K. Walker, D. N. Tower, and F. F. Forbes.

On motion of Mr. Charles W. Sherman, it was voted that the annual meeting adjourn to the third Wednesday in September, at Rutland, Vt.

Adjourned.

The annual "field day" was then observed by an excursion to the works of the Metropolitan Water Works at Spot Pond and Fells Reservoir, and to the reservoirs of the Winchester Water Works.

OBITUARY NOTE.

JOHN C. HASKELL, past president and member of the executive committee of this Association, committed suicide by shooting himself through the heart with a double-barreled shotgun on June 12, 1900.

Mr. Haskell was born in Rochester, Mass., about fifty-five years ago. He had been city engineer of Lynn, and about twelve years ago was elected superintendent of the Lynn Water Works, which position he held until his resignation on May 12. He was elected a member of this Association on Dec. 11, 1889, and has been very prominent in its affairs, having served on many committees, and as president in 1896–1897. He was the author of several papers in the Journal, and frequently took part in the discussions.

He was a member of the Boston Society of Civil Engineers. He was also a Mason and an Odd Fellow. He was unmarried.

WATER WORKS STATISTICS

FOR THE YEARS

1897, 1898 and 1899,

IN FORM ADOPTED BY THE

New England Water Works Association.

COMPILED BY
JOSEPH E. BEALS,
Senior Editor.
1900.

1897.—TABLE I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1	2.—Description of Coal Used.					
						Builders of Pumping Machinery.	*b* Kind.	*c* Size.	*d* Brand.	*e* Price per Ton.	*f* Per Cent. of Ash.	*g* Wood. Price per Cord.
1	Atlantic City, N. J.											
2	Attleboro, Mass. . .	1873	Town.	Well near Seven Mile River.	Pumping to Standpipe.	Blake, Deane.	Bituminous.		Georges Creek.	$4 25		
3	Billerica, Mass. . . .											
4	Boston, Mass. Cochituate	1848	City.	Lake Cochituate, Sudbury River, and Mystic Lake.	65% Gravity Works.	Holly, Quintard, Worthington,	Bituminous.	Broken.		3 47 to 3 57	9.2	
	Mystic . . .	1864			35% Pumping Works.	Blake.	Bituminous.	Broken.		3 18	11.4	
5	Brockton, Mass. . .	1880	City.	Storage Reservoir, Salisbury Brook.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt. . . .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Clearfield.	3 85		
7	Concord, N. H. . . .											
8	Fall River, Mass. . .	1874	City.	Watuppa Lake.	Pumping to Standpipe and Tank.	Worthington, Davidson.			Georges Creek.			
9	Fitchburg, Mass. . .		City.	Storage Reservoir and Pond.	Gravity.							
10	Holyoke, Mass. . . .	1873	City.	Lakes, Streams, and Reservoir.	Gravity.							
11	Keene, N. H.											
12	Lowell, Mass.	1870–96		Driven Wells and Filter Gallery.	Pumping to Reservoir and Direct.	Morris, Deane, Worthington, Knowles.	Bituminous.	Broken.	Cumberland.	3 94		
13	Lynn, Mass.	1870–97	City.	Storage Reservoir and Saugus River.	Pumping.	Morris, Loretz.			Georges Creek.	4 14		
14	Middleboro, Mass. .	1885	F. Dist.	Well.	Pumping to Standpipe.	Deane.	Bituminous.		Georges Creek & Pocahontas.	4 50 3 90		

15	New Bedford, Mass.	1866–69	City.	Storage Reservoir and Acushnet River.	Gravity and Pumping.	McAlpine, Worthington.	Bituminous.		Pocahontas.	$3 55 3 00	7	$4 00
16	New London, Conn.	1872	City.	Lake Konomoc.								
17	Newton, Mass. . . .	1876	City.	Filter Galleryfed by Springs and Driven Wells.	Pumping to Reservoir.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek & Cumberland.	3 66	6	6 00
18	Oberlin, Ohio	1887	Village.	East Branch Vermillion River.	Pumping.	Deane.	Bituminous.			2 24		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.			4 50		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Corliss.	Anthracite.	Pea.	Beaver Meadow.	4 48		
						Cornish, Worthington.	Anthracite and Bituminous.	Pea.	Beaver Meadow.	4 18		4 50
						Nagle.	Anthracite.	Egg.	Wilkesbarre.	5 32		5 00
						Holly.	Anthracite.	Egg.	Wilkesbarre.	5 31		5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 80		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs fed by Springs, Streams, and Surface Water.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond, Lakeville.	Gravity and Pumping.	Holly and Allis.	Bituminous.		Cumberland.	3 85 3 60	8.28 0.43	
24	Troy, N. Y.	1833–98	City.	Storage Reservoir and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 69 2 54	17.81	5 00
25	Waltham, Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Worthington.	Bituminous.		Georges Creek & Pocahontas.	4 10	10.	
26	Wellesley, Mass. . .											
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Worthington, Deane.	Bituminous.		Pocahontas.	4 07	6.4	3 00

1897.—TABLE I., *Continued.*—GENERAL AND PUMPING.

Number.	3 Coal Consumed for the Year. Lbs.	4 Lbs. of Wood ÷3.	5 Total Fuel Consumed for the Year. Lbs.	6 Total Pumpage for the Year in Gallons.	7 Average Static Head against which Pumps Work. Feet.	8 Average Dynamic Head against which Pumps Work. Feet.	9 Number of Gallons per Pound of Coal.	10 Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	11 Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	12 Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	13 Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	14 Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
2	483 536	1 000	484 536	125 716 250	160	175 Blake 188 Deane	260	41 000 000	$13 18	$0 0732	$151 00	$0 842
3	. . .	. .	. . .	. .	. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	5 157 939 7 421 103	1 000	. . .	5 250 063 975 4 572 225 608	. .	. . .	1 017 9 616 1	. . .	5 706 6 122	. . .	. . .	. . .
5	401 955	. .	. . .	391 977 403	. .	43	975 17	. . .	7 17	0 166	104 60	2 43
6	. . .	. .	. . .	282 550 525	289	316	. .	. . .	28 73	0 09	176 46	0 558
7	. . .	. .	. . .	. .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
8	. . .	. .	. . .	1 339 418 534	. .	185 42	331 83	. . .	10 26	. . .	105 66	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	2 367 459	2 400	2 369 859	1 352 724 180	156 72	162 66	571	77 434 333	8 02	0 0493	. . .	. . .
13	567 300 2 285 150	900	567 300 2 286 050	271 907 330 1 423 543 150	. .	172 16 166 72	479 628 80	75 091 208 86 867 596	6 61	0 0394	81 37	0 4855
14	442 480	. .	442 480	71 489 000	180	201	161 56	27 061 836	32 84	0 1636	96 14	0 4775
15	2 891 050	437	2 891 487	2 066 830 472	125 2 131 6 124 7	134 5 133 23 127 04	672 491 831	75 393 352 54 526 055 88 065 751	5 82	0 0443	46 28	0 3523
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
17	1 544 400	8 000	1 552 400	659 284 000	234	253	424	110 000 000	12 28	0 05	168 14	0 66
18	290 000	. .	. . .	24 584 700	80	80	84 8	5 656 000	49 00	0 61	190 80	2 38
19	240 100	. .	. . .	108 868 320	65	66	482 57	26 562 583	15 08	0 22	107 26	1 62
20	35 500 4 913 750 40 501 923 000	. . 500 187 2 203	35 500 4 914 250 40 688 925 293	3 412 572 606 20 599 984 511 964 360	170 3 112 112	175 88 116 66 139	694 500 555	101 860 800 49 259 300 61 141 800	Low Serv. 4 62 High Serv. 16 25	0 0263 0 1105	. . .	. . .
21	449 830	. .	449 830	52 341 850	219	240	116	. . .	83 37	0 347	282 40	1 17
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	718 700 354 100	. .	718 700 354 100	454 765 940	. .	62 42	632 76	32 940 479	11 22	0 1797	108 91	1 74
24	11 476 193	. .	. . .	2 818 753 723	231	242	245 62	49 572 487	12 34	0 051	30 70	. . .
25	2 005 320	. .	. . .	562 307 588	164	180	284	44 571 950	13 88	0 077	71 05	0 395
26	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
27	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	980 225	193	980 418	269 989 707	238	239	275 4	55 624 546	14 41	0 0603	111 16	0 46

Number.	Name of City or Town.	Receipts from Consumers. A — Rates. Domestic.	B — Rates. Manufacturing.	C — Net Receipts for Water.	D — Miscellaneous Receipts.	E — Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	. . .	. . .	. . .	. . .	$ 16 446 69
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] $ 44 043 87	[2] $ 8 785 56	$ 52 829 43	$ 178 20	53 007 63
6	Burlington, Vt.	35 151 38	4 189 65	39 341 03	2 115 86	41 456 89
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 134 679 84	[2] 5 606 66	140 286 50	7 513 38	147 799 88
9	Fitchburg, Mass.	53 185 07	13 242 27	66 427 34	. . .	. . .
10	Holyoke, Mass.	[1] 12 219 85	[2] 64 581 98	76 801 83	. . .	76 801 83
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	122 761 67	50 258 34	173 020 01	8 742 93	181 762 94
14	Middleboro, Mass.	7 732 98	2 912 59	10 285 57	115 98	10 401 55
15	New Bedford, Mass.	92 291 78	7 376 33	99 668 11	98 90	99 767 01
16	New London, Conn.	. . .	. . .	. . .	. . .	42 583 23
17	Newton, Mass.	[1] 83 052 35	[2] 22 394 37	105 446 72	. . .	. . .
18	Oberlin, Ohio	3 584 21	380 00	3 964 21	644 96	4 609 17
19	Plymouth, Mass.	18 239 41	1 286 50	19 525 91	540 19	20 066 10
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	8 047 46	95 56	8 143 02	182 69	8 325 71
22	Springfield, Mass.	[1] 56 806 93	[2] 130 306 73	187 113 66	. . .	. . .
23	Taunton, Mass.	36 542 99	11 421 97	47 964 96	353 85	48 318 81
24	Troy, N. Y.	[1] 21 115 38	[2] 72 553 37	93 668 75	5 656 39	99 325 14
25	Waltham, Mass.	52 582 19	6 213 95	58 796 14	3 808 74	62 604 88
26	Wellesley, Mass.	. . .	. . .	. . .	. . .	. . .
27	Whitman, Mass.	. . .	. . .	. . .	. . .	. . .
28	Woonsocket, R. I.	34 261 28	4 922 13	39 183 41	105 71	39 289 12

[1] Meter Rates. [2] Faucet Rates.

1897.—TABLE II., *Continued.*—FINANCIAL.—MAINTENANCE.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J		K	AA	BB	CC	DD	EE
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Total from Public Fund.	Gross Receipts.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	. . .	$ 7 166 67	$ 7 166 67	$ 23 166 67	$ 7 353 45	$ 11 600 00	$ 18 953 45	$ 4 659 91	$ 23 613 36
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	$ 3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	57 007 63	10 354 88	30 647 50	41 002 30	[3] 16 005 25	57 007 63
6	3 480 00	$ 250 00	1 778 49	$ 333 80	2 561 44	8 403 73	49 860 62	39 210 62	10 650 00	49 860 62	. . .	49 860 62
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	7 000 00	[2] 594 20 155 394 08	51 915 46	103 155 00	155 070 46	323 62	155 394 08
9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	12 779 50	. . .	. . .	. . .	. . .
10	3 000 00	. . .	. . .	439 20	. . .	. . .	. . .	16 147 95	25 000 00	. . .	. . .	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	181 762 94	64 018 31	73 846 24	137 864 55	[3] 43 898 39	181 762 94
14	. . .	. . .	. . .	. . .	. . .	2 000 00	[2] 16 90 12 401 55	4 252 92	2 620 00	6 872 92	[3] 2 500 00 [4] 2 773 00 272 20	12 418 45
15	. . .	. . .	. . .	. . .	70 000 00	70 000 00	169 767 01	27 652 73	68 000 00	95 652 73	[3] 44 000 00 [4] 30 114 28	169 767 01
16	10 600 00	150 00	3 600 00	225 00	. . .	13 575 00	57 158 23	6 192 23	24 540 00	30 732 23	[4] 26 426 00	57 158 23
17	. . .	. . .	. . .	. . .	. . .	. . .	. . .	18 154 93	92 700 00	. . .	. . .	. . .
18	. . .	. . .	. . .	. . .	2 700 00	2 700 00	7 309 17	2 092 70	2 600 00	4 692 70	[4] 2 616 47	7 309 17
19	. . .	. . .	. . .	. . .	. . .	. . .	20 066 10	7 718 17	3 860 00	11 578 17	[4] 3 347 93 5 140 00	20 066 10
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	3 300 00	. . .	. . .	. . .	[1] 515 77 2 570 00	6 415 77	14 741 48	6 541 48	8 200 00	14 741 48	. . .	14 741 48
22	17 840 00	1 640 20	5 015 54	4 481 25	25 000 00	53 976 99	. . .	21 294 11	94 250 00	. . .	. . .	. . .
23	2 500 00	1 756 00	800 00	545 12	817 56	6 418 68	54 737 49	21 131 65	28 408 00	49 539 65	5 197 83	54 737 49
24	. . .	. . .	. . .	. . .	. . .	. . .	99 325 14	61 112 69	10 897 50	72 010 19	[3] 19 137 50 [4] 8 177 45	99 325 14
25	. . .	. . .	. . .	. . .	. . .	. . .	62 604 88	23 113 79	16 840 00	39 953 79	[3] 21 500 00 1 151 09	62 604 88
26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
27	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
28	15 212 50	1 612 26	1 501 18	1 361 49	11 500 00	31 187 43	70 476 55	11 597 35	19 414 74	31 012 09	39 464 46	70 476 55

[1] From Construction. [2] Balance previous year. [3] To Sinking Fund. [4] To Construction Account.

Number.	Name of City or Town.	Receipts.				
		R	S	T	U	V
		Balance from Previous Year.	Bonds Issued.	Appropriations from Tax Levy.	Other Sources.	Total.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	$ 5 720 98	$11 025 00	. . .	$ 67 00	$16 812 98
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	11 149 82	40 000 00	. . .	{ 4 721 67 / 5 155 98 }	61 027 47
6	Burlington, Vt.	. . .	. . .	$ 2 250 00	. . .	2 250 00
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	. . .	. . .	. . .	. . .	. . .
9	Fitchburg, Mass.	. . .	. . .	. . .	7 356 76	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	20 590 35	25 000 00	. . .	2 809 59	48 459 94
14	Middleboro, Mass.	[1] 2 773 33	. . .	. . .	517 65	3 290 98
15	New Bedford, Mass.	{ 37 822 17 / [1]30 114 28 }	. . .	. . .	10 453 64	78 390 09
16	New London, Conn.	{ 62 743 36 / [1]26 426 00 }	. . .	. . .	. . .	89 169 36
17	Newton, Mass.	. . .	61 167 48	. . .	14 622 18	75 789 66
18	Oberlin, Ohio	55 15	. . .	. . .	3 060 72	3 115 87
19	Plymouth, Mass.	{ [1]3 347 93 / 3 253 87 }	. . .	. . .	275 00	6 876 80
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	426 36	26 941 15	1 000 00	726 30	29 093 81
22	Springfield, Mass.	{ 427 27 / [1]26 857 47 }	. . .	. . .	. . .	27 284 74
23	Taunton, Mass.	478 83	20 000 00	. . .	3 788 31	24 267 14
24	Troy, N. Y.	{ [1]8 177 45 / 2 308 90 }	. . .	. . .	. . .	10 486 35
25	Waltham, Mass.	1 674 45	30 000 00	. . .	1 738 95	33 413 40
26	Wellesley, Mass.	. . .	. . .	. . .	. . .	. . .
27	Whitman, Mass.	. . .	. . .	. . .	. . .	. . .
28	Woonsocket, R. I.	. . .	. . .	14 376 84	2 202 13	16 578 97

[1] From Maintenance Account.

Number.	Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total for Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt to Date.	Value of Sinking Fund to Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	$14 034 08	$ 2 778 90	$16 812 98	$ 323 558 97	$ 265 000 00	$ 38 606 78	. . .
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	26 831 753 14	17 911 273 98	9 852 760 01	. . .
5	$38 624 16	. . .	$ 8 638 31	47 262 47	13 765 00	61 027 47	844 463 04	760 000 00	235 000 00	4
6	1 775 55	$ 474 45	. . .	2 250 00	. . .	2 250 00	459 628 09	265 000 00	167 145 95	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	. . .	2 454 819 84	1 925 000 00	503 747 45	5.3
9	1 250 08	11 354 07	2 126 90	14 731 05	. . .	. . .	531 872 43	736 000 00	204 127 57	4.25
10	2 820 03	2 453 07	. . .	. . .	. . .	. . .	1 011 558 62	500 000 00	276 779 65	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	7 599 33	5 425 24	24 689 67	37 714 24	10 745 70	48 459 94	2 363 676 88	1 800 300 00	411 349 10	3.5 to 5
14	2 232 02	1 058 96	. . .	3 290 98	. . .	3 290 98	111 159 23	63 500 00	2 802 18	4
15	27 306 56	10 957 82	. . .	38 264 38	40 125 71	78 390 09	1 740 650 44	580 000 00	13 662 41	5.51
16	9 359 14	1 176 81	21 319 97	31 855 92	57 313 44	89 169 36	629 712 57	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	75 789 66	. . .	75 789 66	2 013 199 99	2 000 000 00	675 000 00	4.7
18	1 458 76	573 49	1 083 62	3 115 87	. . .	3 115 87	79 589 76	55 000 00	520 50	4.5 to 5.75
19	2 196 56	987 46	910 77	4 094 79	2 782 01	6 876 80	257 269 74	92 880 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	11 286 95	1 752 68	4 098 98	17 138 61	[1]515 77 11 439 43	29 093 81	231 587 93	215 000 00	. . .	4
22	22 349 41	. . .	4 508 06	26 857 47	427 27	27 284 74	2 066 236 58	1 575 000 00	280 496 97	5.92
23	6 808 15	6 836 60	9 402 12	23 046 87	1 220 27	24 267 14	1 175 308 73	705 200 00	80 041 65	4
24	2 827 49	. . .	1 013 70	3 841 19	6 645 16	10 486 35	1 281 930 20	273 500 00	51 156 25	4
25	. . .	. . .	. . .	13 652 00	19 761 40	33 413 40	570 977 55	448 000 00	73 440 15	4
26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
27	. . .	. . .	. . .	. . .	. . .	. . .	124 225 34	100 000 00	. . .	4
28	14 376 84	. . .	. . .	. . .	. . .	. . .	471 780 98	. . .	. . .	. . .

[1] To Maintenance.

Number.	Name of City or Town.	1	2	3	4	5	6	7	8	9	10
		Estimated Population.							Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at Date.	Total Gallons Consumed for the Year.	Quantity Used through Domestic Meters. Gallons.	Quantity Used through Manufacturing Meters. Gallons.	Percentage of Total Consumption Metered.	Average Daily Consumption. Gallons.	Each Inhabitant.	Each Consumer.	Each Tap.
1	Atlantic City, N. J.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
2	Attleboro, Mass.	8 700	7 200	6 700	125 716 250	. . .	. . .	. .	352 086	40 4	52 5	. .
3	Billerica, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
4	Boston, Mass. { Cochituate	491 100	. .	488 100	21 121 552 400	4 911 650 000		23 3	57 867 300	117 8	118 5	. .
	Mystic	142 600	. .	141 600	4 569 393 100	826 417 500		18 9	12 518 900	87 8	88 4	. .
5	Brockton, Mass.	35 000	33 000	31 500	391 977 403	110 845 545	52 537 170	. .	1 073 910	30 68	34 09	222 38
6	Burlington, Vt.	17 700	17 300	17 100	282 550 525	104 301 121	21 761 250	44 6	774 111	44	45	247
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
8	Fall River, Mass.	101 106	. .	97 500	1 339 418 534	. . .	. . .	. .	3 669 640	36 29	37 64	. .
9	Fitchburg, Mass.	29 000	25 000	21 000	933 000 000	81 636 000	275 000 000	. .	. . .	88	121	613
10	Holyoke, Mass.	44 835	44 335	43 835	1 375 000 000	211 322 000		. .	3 769 093	85 33	87 33	1 125
11	Keene, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
12	Lowell, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
13	Lynn, Mass.	68 300	. .	66 000	1 694 258 389	270 236 000		. .	4 641 804	. .	70 16	. .
14	Middleboro, Mass. { Town,	7 000										
	F. Dist.	4 200	4 000	3 800	71 489 000	. . .	. . .	. .	195 860	46 6	51 5	262
15	New Bedford, Mass.	60 000	51 000	50 000	2 071 702 478	61 828 072	280 223 040	16 5	5 675 897	95	113	641
16	New London, Conn.	15 500	15 000	14 500	460 269 788	. . .	. . .	. .	1 261 013	81	87	449
17	Newton, Mass.	30 000	29 600	29 400	658 300 000	278 000 000	46 000 000	. .	1 803 500	60 1	61 3	274
18	Oberlin, Ohio	4 600	3 500	2 000	24 584 700	6 000 000	1 900 000	33	67 200	14 6	33 6	143
19	Plymouth, Mass.	8 000	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
20	Providence, R. I.	166 000	. .	. .	3 151 799 626	. . .	. . .	. .	8 635 067	52	. .	432
21	Reading, Mass.	4 750	4 160	3 650	52 341 850	6 523 493	894 448	. .	143 065	30 12	39 17	161 2
22	Springfield, Mass.	56 689	50 000	44 000	1 825 000 000	358 841 156		19 66	5 000 000	88	113	573
23	Taunton, Mass.	27 093	26 900	26 801	454 765 740	80 889 135	120 481 185	. .	1 243 194	45 8	46	304
24	Troy, N. Y.	65 000	60 000	58 000	3 660 538 723	389 929 756		. .	10 028 873	154	172	1 423
25	Waltham, Mass.	21 900	21 300	20 800	562 307 588	31 931 962		. .	1 540 569	70	74	492
26	Wellesley, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
27	Whitman, Mass.	6 000	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
28	Woonsocket, R. I.	28 500	26 500	26 000	271 236 620	212 805 403		. .	742 841	26	28	380

1897.—TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During the Year in Feet.	4 Length Discontinued During the Year in Feet.	5 Total Length in Use. Miles.	6 Cost of Repairs per Mile.	7 Number of Leaks for Year.	8 Length of Pipe Less than 4 in. Diam. Miles.	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number Blow-off Gates.	15 Range of Pressure on Mains at Center for Day and Night Pounds.
1	Atlantic City, N. J.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	Attleboro, Mass.	C. I. & C. L.	4 to 16	1 273	. .	29 82	. .	13 00	. .	2	236	. .	. .	. .	. .	50 to 62
3	Billerica, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	Boston, Cochituate	C. I.	4 to 48	102 960	. .	627 1	. .	. .	2 2	178	6 547	323	7 410	. .	. .	. .
	Mass. Mystic	C. I., W. I. & Cem.	3 to 36	13 728	. .	187 2	. .	. .	4 00	79	1 718	128	2 519	. .	. .	. .
5	Brockton, Mass.	W. I., C. L. & C. I.	6 to 30	23 440	0	61 28	$ 0 52	10 19	. .	46	565	54	630	. .	18	47 to 56
6	Burlington, Vt.	C. L., C. I. & W. I.	4 to 30	2 094	6 918	36 00	8 22	10 42	3 00	15	205	28	541	62	12	70 to 85
7	Concord, N. H.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
8	Fall River, Mass.	C. I.	6 to 24	. .	. .	62 3	. .	. .	. .	55	882	50	861	. .	. .	80
9	Fitchburg, Mass.	W. I., C. L. & C. I.	2 to 30	7 020	. .	63 42	3 57	36 00	1 33	14	439	25	519	. .	. .	155 to 160 75 to 80
10	Holyoke, Mass.	W. I. & C. I.	½ to 20	3 266	0	63 00	4 20	4 00	5 6	5	426	15	545	1	17	45 to 65 80 to 100
11	Keene, N. H.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	Lowell, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
13	Lynn, Mass.	W. I., C. L. & C. I.	2 to 20	2 125	. .	109 24	. .	146 00	. .	1	171	6	942	. .	. .	50 to 65
14	Middleboro, Mass.	C. I.	4 to 12	2 797	. .	15 95	. .	0	. .	4	112	6	154	. .	5	45 to 60
15	New Bedford, Mass.	W. I. C. L. & C. I.	4 to 36	27 566	8 844	87 51	9 17	7 00	1 2	23	693	46	974	72	91	28 to 39
16	New London, Conn.	W. I. C. L. & C. I.	4 to 20	1 686	0	45 00	18 29	10 7	3 00	5	212	17	259	. .	29	45 to 50
17	Newton, Mass.	C. I.	4 to 20	27 026	0	130 8	12 15	15 00	2 9	44	879	51	735	46	343	84
18	Oberlin, Ohio	C. I.	4 to 12	1 730	0	8 1	0	0	0 33	2	74	3	48	2	2	27 to 32
19	Plymouth, Mass.	W. I. & C. L.	2 to 20	2 922	0	36 9	9 38	11 00	10 5	2	120	6	325	129	22	. . .
20	Providence, R. I.	Low Serv., C. I.	6 to 36	38 270	499	310 35	. .	. .	0	33	1 787	92	3 216	. .	32	64 to 73
		High Serv. Fire, C. I.	12, 16, 24	. .	. .	5 57	. .	. .	. .	. .	89	. .	31	. .	4	114
21	Reading, Mass.	C. I.	4 to 12	14 093	0	23 08	0	0	0	10	121	13	208	0	14	68 to 78
22	Springfield, Mass.	W. I., W. I. C. L. & C. I.	¾ to 36	44 902	8 434	134 71	7 57	85 00	7 3	51	892	138	1 083	297	86	100 to 120 30 to 35
23	Taunton, Mass.	C. I.	4 to 30	11 300	0	73 7	40 63	5 00	1 25	13	737	12	504	11	52	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	3 603	16	58 81	5 74	20 00	0 56	7	762	8	1 272	. .	37	9 to 107
25	Waltham, Mass.	C. I., W. I. & C. L.	2 to 24	2 287	. .	49 00	2 10	10 4	. .	15	306	10	633	. .	. .	58
26	Wellesley, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
27	Whitman, Mass.	C. L. & C. I.	. .	. .	. .	17 00	. .	. .	. .	. .	148	. .	. .	. .	. .	65
28	Woonsocket, R. I.	C. I.	4 to 20	4 320	. .	43 47	2 17	0	0	9	523	10	426	. .	16	50 to 120

[1] Per mile.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind.	Size. Inches.	Extended. Feet.	Discontinued. Feet.	Total in Use. Miles.	Added.	Total in Use.	Average Length of Services.	Average Cost of Services.	Added.	Now in Use. Domestic.	Now in Use. Manufacturing.	Added.	Total in Use.
1	Atlantic City, N. J.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .	.	.	. .
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	67	740		0	0
3	Billerica, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .		.	. .
4	Boston, { Cochituate	Lead.	5/8 to 6	56 075	. .	. .	2 465	75 785	. .	. .	.	4 436		.	625
	Mass. { Mystic	Lead, W. I.	1/2 to 4	23 369	. .	. .	906	25 848	. .	. .	.	501		.	21
5	Brockton, Mass.	W. I., L. L., C. L., C. I.	3/4 to 6	12 168	503	26 39	226	4 829	45 74	. .	319	3 701		.	. .
6	Burlington, Vt.	G. I., Lead.	1/2 to 6	2 177	70	17 00	70	3 137	30 00	7 28	249	1 752	49	3	33
7	Concord, N. H.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .		.	. .
8	Fall River, Mass.	Lead.	1/2 to 2	. .	. .	. .	317	6 422	. .	. .	347	5 954		.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	3/4 to 8	7 194	. .	45 42	118	4 169	61	21 35	160	1 841	190	10	80
10	Holyoke, Mass.	C., R. L., Enam., C. I., Lead.	5/8 to 4	1 980	4	13 04	99	3 444	20	14 56	4	200		1	45
11	Keene, N. H.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .		.	. .
12	Lowell, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .		.	. .
13	Lynn, Mass.	I., C. L., Adam., G. I., L. L.	3/4 to 10	9 151	870	. .	{ Saugus 54 / { Lynn 185	802 / 11 374	51 4 / 42 9	.	307	1 868		.	. .
14	Middleboro, Mass.	C. L., Lead.	3/4 to 3	1 267	. .	8 28	26	747	50 0	. .	19	292		0	6
15	New Bedford, Mass.	Lead, C. I.	1/2 to 10	18 803	552	56 52	413	8 860	44 0	18 09	255	556	62	29	110
16	New London, Conn.	W. I. C. L., G., C. I., L.	1/2 to 4	1 532	0	10 3	70	2 811	22 0	11 91	10	197		1	16
17	Newton, Mass.	L., W. I., C. I.	1/2 to 6	18 250	4 000	73 8	297	6 573	59 0	23 00	426	5 100	25	0	17
18	Oberlin, Ohio	G. I., Lead.	3/4 to 2	. .	. .	. .	28	471	25 0	8 00	37	169	5	0	0
19	Plymouth, Mass.	L., C. L.	1/2 to 1	452	. .	5 65	51	1 711	17 67	4 50	.	. .		0	1
20	Providence, R. I.	L., C. I.	1/2 to 10	. .	. .	. .	698	19 993	. .	. .	893	15 679		6	138
21	Reading, Mass.	G. I., C., L., L. L., C. I.	3/4 to 6	5 344	481	11 19	75	887	71 12	23 36	51	186		0	3
22	Springfield, Mass.	W. I., C. I.	1/2 to 6	. .	. .	. .	423	8 721	. .	. .	197	2 496		2	174
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	3/4 to 3	7 075	6 015	39 67	145	4 090	. .	21 49	95	1 386	150	0	14
24	Troy, N. Y.	L., C. I.	3/4 to 6	. .	. .	1 33	194	. .	35 0	25 00	15	278		.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	3/4 to 8	4 113	42	35 4	44	3 130	93 0	25 18	0	75		0	6
26	Wellesley, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. . .		.	. .
27	Whitman, Mass.	. . .	. .	. .	. .	. .	. . .	903	. .	. .	.	. . .		.	. .
28	Woonsocket, R. I.	L., I.	5/8 to 6	1 083	. .	5 7	80	1 952	12 8	11 71	86	1 637	48	3	12

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1	2.—Description of Coal Used.					
						Builders of Pumping Machinery.	*b* Kind.	*c* Size.	*d* Brand.	*e* Price per Ton.	*f* Per Cent. of Ash.	*g* Wood. Price per Cord.
1	Atlantic City, N. J.	1882 1888	City.	Driven Wells and Absecon Creek. Five Artes'n Wells	Pumping to Standpipe and Direct.	Worthington, Gordon-Maxwell, Smith-Vaile.	Bituminous. Anthracite.	Run of Mine. Pea.		$2 94 2 74 3 27 3 52	5 9.85	
2	Attleboro, Mass. . .	1873	Town.	Circular Well near Seven Mile River.	Pumping to Standpipe.	Blake, Deane.	Bituminous.		Georges Creek.	4 15		
3	Billerica, Mass. . . .											
4	Boston, Mass. . . .											
5	Brockton, Mass. . .	1880	City.	Storage Reservoir on Salisbury Brook.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt. . . .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Reynoldsv'll	2 67		
7	Concord, N. H. . . .	1872	City.	Penacook Lake.	Gravity and Pumping.		Bituminous.		Pocahontas.			
8	Fall River, Mass. . .	1874	City.	Watuppa Lake.	Pumping to Standpipe.	Worthington, Deane.	Bituminous.		Georges Creek.			
9	Fitchburg, Mass. . .		City.	Storage Reservoirs.	Gravity.							
10	Holyoke, Mass. . . .	1873	City.	Natural Lakes, Mountain Streams, and Storage Reservoirs.	Gravity.							
11	Keene, N. H.											
12	Lowell, Mass.	1870–96	City.	Driven Wells and Filter Gallery.	Pumping to Reservoir and Direct.	Morris, Worthington, Deane, Knowles.	Bituminous.	Broken.	Cumberland.	3 42		
13	Lynn, Mass.	1870–98	City.	Storage Basins.	Pumping to Reservoir.	Leavitt, Loretz.			Georges Creek.	3 64		

14	Middleboro, Mass. .	1885	F. Dist.	Well.	Pumping to Standpipe and Direct.	Deane.	Bituminous.		Georges Creek & Pocahontas.	$3 90 3 85		
15	New Bedford, Mass.	1866–69	City.	Storage Reservoir.	Gravity and Pumping.	McAlpine, Worthington.	Bituminous.		Pocahontas.	3 00 3 50	7	$4 00
16	New London, Conn.	1872	City.	Lake Konomoc.								
17	Newton, Mass. . . .	1876	City.	Filter Gallery fed by Springs and Driven Wells.	Pumping to Reservoir.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek.	3 50	7	6 00
18	Oberlin, Ohio	1887	Village.	East Branch Vermillion River.	Pumping.	Deane.	Bituminous.	Run of Mine.	Pocahontas.	3 36		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.			4 50		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Cornish, Worthington.	W. Anthracite and Bituminous.	Pea.	Beaver Meadow, Georges Creek.	3 91		4 50
						Corliss, Nagle and Holly.	H. Anthracite	Egg.	Wilkesbarre, Reading.	5 32		5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 70		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond, Lakeville.	Gravity and Pumping Direct.	Holly, Allis.	Bituminous.		Cumberland.	3 35 3 75	8.28 0.43	
24	Troy, N. Y.	1833–99	City.	Five Artificial Storage Reservoirs and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 57 2 54	18.27	5 00
25	Waltham, Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Barr, Worthington.	Bituminous.		Georges Creek.	4 14	10.	
26	Wellesley, Mass. . .	1884	Town.	Two Wells.	Pumping to Reservoir.	Blake.	Bituminous.		Georges Creek and Puritan.	4 04	10.4	3 50
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Deane, Worthington.	Bituminous.		Georges Creek.	4 54	6.65	3 00

1898.—TABLE I., *Continued.*—PUMPING.

Number.	3 Coal Consumed for the Year. Lbs.	4 Lbs. of Wood ÷ 3.	5 Total Fuel Consumed for the Year. Lbs.	6 Total Pumpage for the Year in Gallons.	7 Average Static Head against which Pumps Work. Feet.	8 Average Dynamic Head against which Pumps Work. Feet.	9 Number of Gallons per Pound of Coal.	10 Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	11 Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	12 Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	13 Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	14 Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	{ 2 427 232 { 843 623	. .	. . .	691 296 932 146 300 383	81 119 5	110 5 119 5	285 173 4	26 347 500 17 283 000	$ 8 99 23 49	$0 0814 0 1915	$ 30 84	$0 275
2	516 675	1 000	517 675	130 526 640	160	{ 175 { 188	252	39 400 000	22 09	0 1177	145 17	0 772
3	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
4	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
5	399 408	. .	. . .	366 187 044	. .	43	916 82	. . .	. . .	. . .	. . .	. . .
6	. . .	. .	. . .	294 118 350	289	316	. .	. . .	25 61	0 08	148 13	0 468
7	256 220	. .	. . .	124 393 311	. .	. . .	485	. . .	. . .	. . .	. . .	. . .
8	3 512 320	. .	. . .	1 144 657 850	. .	184 69	325 82	. . .	9 83	. . .	124 04	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	9 057 728	2 400	9 060 128	3 517 663 230	156 33	163 77	275	79 360 607	. . .	. . .	. . .	. . .
13	{ 235 900 { 2 517 160	1 310	{ 235 900 { 2 518 470	133 450 140 1 598 126 150	. . . .	167 52 164 22	565 70 634 80	79 035 791 86 954 554	6 04	0 0367	72 65	0 4428
14	475 650	. .	475 650	78 163 000	180	201	164 33	27 514 066	31 11	0 155	86 61	0 4325
15	{ 1 344 100 { 527 300 { 1 248 600	152 71 73	1 344 252 527 371 1 248 673	910 443 881 241 975 116 1 024 833 324	124 7 131 62 124 9	134 02 133 20 127 26	677 459 821	75 702 140 50 971 186 87 108 891	5 44	0 0416	52 54	0 4018
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
17	1 536 400	8 000	1 544 400	640 373 316	234	254	414	92 000 000	11 99	0 047	178 00	0 70
18	272 000	. .	. . .	29 210 000	80	80	108	7 165 000	47 90	0 60	168 50	2 11
19	230 332	14 100	244 432	111 567 456	65	66	484 37	26 661 662	13 50	0 20	81 83	1 24
20	{ *w* 5 242 600 { *h* 908 420	450 1 362	5 243 050 909 782	3 552 860 464 538 771 535	170 3 112	175 88 139	678 593	99 397 800 68 651 200	4 32 15 35	0 0245 0 1038	. . .	. . .
21	359 119	. .	359 119	41 074 585	219	240	115	. . .	91 07	0 379	340 89	1 42
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	{ 740 600 { 331 000	. . . .	{ 740 600 { 331 000	475 817 605	. .	61 69	642 48	33 055 035	10 01	0 1623	107 05	1 735
24	12 119 578	. .	. . .	3 108 279 059	231	242	256 47	51 762 342	11 50	0 0475	. . .	. . .
25	1 981 355	. .	. . .	620 034 502	164	180	{ 288 { 615	46 977 840	15 47	0 086	68 00	0 378
26	433 480	120	433 600	60 869 466	250	278	140	32 479 785	39 70	0 142	278 63	1 002
27	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	961 900	502	962 402	269 628 974	238	239	. .	55 962 698	13 60	0 057	111 86	0 46

w Worthington. *h* Holly.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates. Domestic.	Rates. Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	$ 65 888 70	$ 5 742 20	$ 71 630 90
2	Attleboro, Mass.	. . .	. . .	16 394 18	. . .	16 394 18
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] $ 48 166 64	[2] $ 8 010 32	56 176 96	1 456 44	57 623 40
6	Burlington, Vt.	37 241 45	2 874 41	40 115 86	637 64	40 753 50
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 142 025 27	[2] 5 242 33	147 267 60	4 007 51	151 275 11
9	Fitchburg, Mass.	50 957 40	15 316 09	66 273 49	. . .	66 273 49
10	Holyoke, Mass.	[1] 12 776 63	[2] 66 168 94	78 945 57	7 059 13	86 004 70
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	119 251 45	57 139 78	176 391 23	9 959 07	186 350 30
14	Middleboro, Mass.	[1] 6 866 56	[2] 4 121 89	10 988 45	142 27	11 130 72
15	New Bedford, Mass.	93 657 79	6 459 08	100 116 87	95 00	100 211 87
16	New London, Conn.	. . .	. . .	. . .	. . .	44 539 19
17	Newton, Mass.	[1] 91 345 76	[2] 21 925 35	. . .	. . .	. . .
18	Oberlin, Ohio	4 242 73	328 00	4 570 73	133 31	4 704 04
19	Plymouth, Mass.	19 060 18	1 550 62	20 610 80	308 11	20 918 91
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	6 227 43	182 14	6 409 57	136 18	6 545 75
22	Springfield, Mass.	[1] 61 689 54	[2] 134 921 41	196 610 95	18 211 34	214 822 29
23	Taunton, Mass.	39 925 62	12 039 12	51 964 74	403 08	52 367 82
24	Troy, N. Y.	[1] 21 423 89	[2] 73 894 17	95 318 06	7 229 31	102 547 37
25	Waltham, Mass.	54 230 29	6 242 45	60 472 74	4 500 54	64 973 28
26	Wellesley, Mass.	11 097 79	362 88	11 460 67	74 81	11 535 48
27	Whitman, Mass.	[1] 4 209 74	[2] 2 512 50	6 722 24	642 29	7 364 53
28	Woonsocket, R. I.	34 239 99	6 183 81	40 423 80	138 95	40 562 75

[1] Meter Rates. [2] Faucet or Schedule Rates.

1898.—TABLE II., *Continued.*—FINANCIAL.—MAINTENANCE.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J	Total from Public Funds.	K	AA	BB	CC	DD	EE
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.		Gross Receipts.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	$30 000 00	$30 000 00	$101 630 90	$31 340 49	$ 43 520 00	$ 74 860 49	[1] $24 500 00 2 270 41	$101 630 90
2	. . .	. . .	. . .	. . .	7 208 34	7 208 34	23 602 52	6 888 56	12 060 00	18 948 56	[1] 4 650 00 3 96	23 602 52
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	$ 3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	61 633 40	9 477 48	31 302 50	40 779 98	[1] 20 853 42	61 633 40
6	3 480 00	$ 250 00	1 877 28	$ 235 70	. . .	5 842 98	46 956 48	33 196 80	10 365 00	43 561 80	[1] 2 360 25 674 43	46 596 48
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	. . .	. . .	45 331 53	103 490 00	148 821 53	. . .	. . .
9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	22 399 01	. . .	. . .	. . .	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	32 137 17	25 000 00	57 137 17	[1] 500 00	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	186 350 30	50 953 24	74 846 24	125 799 48	[1] 60 550 82	186 350 30
14	. . .	. . .	. . .	. . .	. . .	2 000 00	13 130 72	4 245 30	2 540 00	6 785 30	[2] 2 141 64 [1] 3 100 00	12 026 94
15	. . .	. . .	. . .	. . .	87 000 00	87 000 00	187 211 87	34 398 79	80 000 00	114 398 79	* [1] 29 600 00 [2] 23 213 08	187 211 87
16	11 400 00	150 00	3 600 00	225 00	. . .	15 375 00	59 914 19	6 927 31	24 540 00	31 467 31	[2] 28 446 88	59 914 19
17	. . .	. . .	. . .	. . .	. . .	. . .	. . .	17 987 62	96 000 00	. . .	. . .	. . .
18	. . .	. . .	. . .	. . .	4 676 89	4 676 89	9 380 93	2 424 00	2 499 08	4 923 08	[2] 1 457 85 [1] 3 000 00	9 380 93
19	. . .	. . .	. . .	. . .	. . .	. . .	20 918 91	9 385 13	3 654 40	13 039 53	** [2] 2 739 38	20 918 91
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	3 630 00	. . .	. . .	. . .	2 230 00	5 860 00	. . .	5 376 87	8 600 00	13 976 87	. . .	. . .
22	18 620 00	1 680 00	5 099 71	5 642 28	. . .	31 041 99	. . .	21 631 68	92 500 00	. . .	. . .	. . .
23	2 500 00	2 411 21	800 00	367 66	1 692 74	7 771 61	60 139 43	22 327 82	28 608 00	50 935 82	[1] 9 203 61	60 139 43
24	. . .	. . .	. . .	. . .	. . .	. . .	102 547 37	58 852 37	9 960 00	68 812 37	[1] 19 650 00 [2] 14 085 00	102 547 37
25	. . .	. . .	. . .	. . .	. . .	. . .	64 973 28	24 257 59	17 920 00	42 177 59	[1] 22 172 12 623 57	64 973 28
26	4 720 00	400 00	200 00	199 45	. . .	5 519 45	17 054 93	6 180 13	10 780 00	16 960 13	. . .	. . .
27	3 200 00	. . .	. . .	. . .	. . .	3 200 00	10 564 53	3 888 73	4 000 00	7 888 73	[2] 2 675 80	10 564 53
28	15 475 00	1 627 99	1 780 06	885 69	11 257 85	31 026 59	71 589 34	11 298 52	18 871 24	30 169 76	41 419 58	71 589 34

[1] To Sinking Fund. [2] To Construction. * Bonds paid, $20,000.00. ** Bonds paid, $5,140.00.

Number.	Name of City or Town.	Receipts.				
		R	S	T	U	V
		Balance from Previous Year.	Bonds Issued.	Appropriations from Tax Levy.	Other Sources.	Total.
1	Atlantic City, N. J.	. . .	. . .	$ 2 500 00	$ 198 80	$ 2 698 80
2	Attleboro, Mass.	$ 2 778 90	$14 820 00	. . .	154 69	17 753 59
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	13 765 00	10 000 00	. . .	5 889 52	29 654 52
6	Burlington, Vt.	. . .	. . .	3 485 22	. . .	3 485 22
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	6 444 67	25 000 00	7 000 00	. . .	38 444 67
9	Fitchburg, Mass.	. . .	. . .	. . .	4 083 53	4 083 53
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	11 277 06	35 000 00	. . .	3 002 19	49 279 25
14	Middleboro, Mass.	[1] 2 141 64	. . .	. . .	484 17	2 625 81
15	New Bedford, Mass.	{ 40 125 71	. . .	. . .	7 278 63	70 617 42
		{ [1] 23 213 08				
16	New London, Conn.	{ 52 338 69	. . .	. . .	. . .	80 785 57
		{ [1] 28 446 88				
17	Newton, Mass.	. . .	41 037 23	. . .	1 563 56	42 600 79
18	Oberlin, Ohio	281 10	. . .	. . .	1 757 20	2 038 30
19	Plymouth, Mass.	{ [1] 2 739 38	. . .	. . .	255 50	5 738 49
		{ 2 743 61				
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	6 439 43	7 730 20	. . .	517 21	14 686 84
22	Springfield, Mass.	. . .	. . .	. . .	. . .	. . .
23	Taunton, Mass.	1 220 27	20 000 00	. . .	3 268 72	24 488 99
24	Troy, N. Y.	{ 6 645 16	. . .	. . .	. . .	20 730 16
		{ [1] 14 085 00				
25	Waltham, Mass.	19 761 40	5 000 00	. . .	6 931 05	31 692 45
26	Wellesley, Mass.	3 795 52	7 000 00	. . .	1 969 91	12 765 43
27	Whitman, Mass.	{ [1] 2 675 80	. . .	. . .	10 75	3 898 30
		{ 1 211 75				
28	Woonsocket, R. I.	. . .	. . .	10 918 93	2 084 00	13 002 93

[1] From Maintenance Account.

Number.	Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total for Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt to Date.	Value of Sinking Fund to Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	$ 2 668 27	. . .	. . .	$ 2 668 27	$ 30 53	$ 2 698 80	$ 893 309 50	$ 887 000 00	$ 55 141 63	4.937
2	. . .	. . .	. . .	11 968 50	5 785 09	17 753 59	335 527 47	278 000 00	47 442 96	. . .
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	14 318 59	. . .	$ 5 713 82	20 032 41	9 622 11	29 654 52	864 495 45	770 000 00	264 506 11	4
6	2 899 75	$ 585 47	. . .	3 485 22	. . .	3 485 22	463 113 31	258 500 00	181 572 88	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	25 000 00	. . .	13 444 67	38 444 67	. . .	38 444 67	. . .	1 950 000 00	549 591 70	5.3
9	1 182 75	6 596 14	1 183 75	8 962 64	. . .	. . .	484 874 66	636 000 00	151 125 34	4.3
10	33 388 72	. . .	. . .	. . .	. . .	. . .	1 118 259 63	500 000 00	289 190 50	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	4 262 16	4 290 39	27 310 86	35 863 41	13 415 84	49 279 25	2 396 788 65	1 835 300 00	486 692 08	3.5 to 5
14	1 874 79	656 33	94 69	2 625 81	. . .	2 625 81	113 283 87	61 500 00	4 015 71	4
15	28 432 80	6 344 51	. . .	34 777 31	35 840 11	70 617 42	1 775 427 75	560 000 00	91 012 12	4.49
16	21 857 14	1 316 07	14 117 04	37 290 25	43 495 32	80 785 57	667 008 32	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	. . .	. . .	42 600 79	2 054 251 23	2 075 000 00	735 346 06	4.7
18	1 180 10	858 20	. . .	2 038 30	. . .	2 038 30	82 442 72	50 000 00	68 93	4.5 & 5.75
19	449 51	754 57	1 785 03	2 989 11	2 749 38	5 738 49	259 655 55	87 740 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	1 797 52	1 287 89	9 975 03	13 060 44	. . .	. . .	244 131 16	215 000 00	. . .	4
22	16 042 36	. . .	1 201 58	17 243 94	. . .	. . .	2 083 480 52	1 550 000 00	332 886 64	5.91
23	12 878 99	8 211 39	2 412 56	23 502 94	986 05	24 488 99	1 195 542 95	725 200 00	106 077 22	4
24	11 164 31	. . .	. . .	11 164 31	9 565 85	20 730 16	1 293 094 51	246 000 00	42 962 50	4
25	. . .	. . .	. . .	24 874 47	6 817 98	31 692 45	. . .	406 000 00	49 601 67	4
26	2 900 74	1 314 30	6 015 16	10 230 20	. . .	. . .	306 107 06	275 000 00	70 080 31	4
27	. . .	. . .	. . .	1 663 70	2 234 60	3 898 30	125 889 04	100 000 00	. . .	4
28	10 918 93	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Number.	Name of City or Town.	1	2	3	4	5	6	7	8	9	10
		Estimated Population.							Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at Date.	Total Gallons Consumed for the Year.	Quantity Used through Domestic Meters. Gallons.	Quantity Used through Manufacturing Meters. Gallons.	Average Daily Consumption. Gallons.	Each Inhabitant.	Each Consumer.	Each Tap.
1	Atlantic City, N. J.	25 000	24 500	. .	837 597 315	. . .	. . .	. . .	50	. .	622
2	Attleboro, Mass.	8 900	7 400	6 900	130 526 640	. . .	. . .	357 688	40 1	51 8	. .
3	Billerica, Mass.	. . .	. .	. .	. . .	. . .	. . .	. . .	. .	. .	. .
4	Boston, Mass.	. . .	. . .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .
5	Brockton, Mass.	35 000	33 200	31 600	366 187 044	141 013 762	37 325 625	1 003 252	28 66	31 11	202 39
6	Burlington, Vt.	18 000	17 600	17 400	294 118 350	120 979 500	14 785 500	46 805 800	45	46	251
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .
8	Fall River, Mass.	97 517	. .	94 267	1 144 657 850	. . .	. . .	3 136 049	32 16	33 26	. .
9	Fitchburg, Mass.	29 000	25 000	23 000	940 000 000	72 400 000	285 000 000	. . .	91	122	604
10	Holyoke, Mass.	44 982	44 482	43 982	1 375 000 000	198 907 750		3 769 093	83 79	85 69	1 076
11	Keene, N. H.	. . .	. .	. .	. . .	. . .	. . .	. . .	. .	. .	. .
12	Lowell, Mass.	. . .	. .	. .	2 454 575 265	. . .	. . .	6 724 865	. .	78	. .
13	Lynn, Mass.	70 700	. .	68 000	1 732 220 852	260 000 000		4 745 810	. .	69 79	. .
14	Middleboro, Mass.	{ Town 7 000 F.Dist. 4 200 }	4 000	3 750	78 163 000	11 328 848	25 603 436	214 145	51	57 12	278 5
15	New Bedford, Mass.	58 000	51 000	50 000	2 156 277 643	68 100 337	246 866 887	14 6	5 907 610	102	118	655
16	New London, Conn.	15 800	15 300	14 800	472 064 049	. . .	. . .	1 293 320	82	87	447 2
17	Newton, Mass.	30 000	29 600	29 400	641 589 600	293 000 000	44 000 000	1 757 780	58 6	59 8	259
18	Oberlin, Ohio	4 700	3 500	2 500	29 210 000	8 875 000	1 640 000	35 80 000	17	32	142
19	Plymouth, Mass.	. . .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .
20	Providence, R. I.	170 200	. .	. .	3 339 382 586	. . .	. . .	9 148 993	54	. .	447
21	Reading, Mass.	4 750	4 160	3 650	41 074 585	. . .	. . .	112 533	23 69	30 83	161 2
22	Springfield, Mass.	57 676	50 800	45 500	1 877 012 500	405 371 533		21 6 5 142 500	89	113	567
23	Taunton, Mass.	27 093	26 950	26 840	475 817 605	64 594 282	126 584 192	. . 1 303 610	48	48 6	308
24	Troy, N. Y.	65 000	61 000	58 000	3 929 001 559	410 356 723		. . 10 764 388	165	185	1 472
25	Waltham, Mass.	22 400	21 600	21 200	620 034 502	32 822 478		. . 1 698 425	76	80	532
26	Wellesley, Mass.	4 229	4 024	3 874	60 869 466	38 264 515	762 622	. . 166 765	39	43	207
27	Whitman, Mass.	6 000	. .	. .	. . .	. . .	. . .	. . .	. .	. .	. .
28	Woonsocket, R. I.	28 500	26 500	26 000	269 565 879	. . .	. . .	. . 748 107	26	28	372

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Pipe. Inches.	3 Length Extended During the Year in Feet.	4 Length Discontinued During the Year in Feet.	5 Total Length in Use. Miles.	6 Cost of Repairs per Mile.	7 Number of Leaks for Year.	8 Length of Pipe Less than 4 in. Diam. Miles.	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number Blow-off Gates.	15 Range of Pressure on Mains at Center for Day and Night. Pounds.
1	Atlantic City, N. J.	C. I.	4 to 20	5 784	0	42 65	. .	. .	2 0	11	436	. .	. .	. .	9	. . . .
2	Attleboro, Mass.	C. I., C. L.	4 to 16	2 466	. .	30 28	. .	12	. .	9	245	. .	. .	. .	. .	54 to 62
3	Billerica, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . . .
4	Boston, { Cochituate / Mass. { Mystic	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . . .
5	Brockton, Mass.	W. I., C. L., C. I.	6 to 30	7 426	1 012	62 49	$ 0 47	[1] 0 09	. .	11	576	22	707	. .	19	47 to 56
6	Burlington, Vt.	C. L., C. I., W. I.	4 to 30	3 833	7 837	37 0	8 50	[1] 0 22	2 6	2	205	49	573	56	12	70 to 85
7	Concord, N. H.	. . .	¾ to 20	13 505	3 834	59 22	. .	. .	. .	7	260	23	720	. .	. .	. . . .
8	Fall River, Mass.	C. I.	6 to 24	. .	. .	84 8	. .	. .	. .	30	912	44	905	. .	. .	80
9	Fitchburg, Mass.	W. I., C. L., C. I.	2 to 30	1 577	. .	63 72	1 97	6	1 33	8	447	9	528	. .	. .	{ 155 to 160 / 75 to 80
10	Holyoke, Mass.	W. I., C. I.	½ to 30	81 067	0	78 37	2 52	2	5 62	60	807	129	674	1	25	{ 45 to 65 / 80 to 100
11	Keene, N. H.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . . .
12	Lowell, Mass.	C. I.	. .	14 046	. .	124	. .	. .	. .	12	1 123	46	1 144	. .	. .	. . . .
13	Lynn, Mass.	W. I., C. L., C. I.	2 to 20	2 232	. .	109 6	. .	115	. .	1	794	6	948	. .	. .	50 to 65
14	Middleboro, Mass.	C. I.	4 to 12	1 112	. .	16 17	. .	0	. .	2	114	4	158	. .	5	45 to 60
15	New Bedford, Mass.	C. I.	4 to 36	16 033	6 403	89 33	14 81	8	1 18	20	713	38	1 012	72	93	28 to 39
16	New London, Conn.	C. I., W. I., C. L.	4 to 20	5 726	0	46 1	17 37	[1] 0 69	3 1	16	228	15	274	. .	30	45 to 50
17	Newton, Mass.	C. I.	4 to 20	15 736	1 000	133 6	13 50	6	0 22	24	903	39	774	40	360	84
18	Oberlin, Ohio	C. I.	4 to 12	1 668	0	8 8	0	0	0 33	3	83	2	53	2	2	27 to 32
19	Plymouth, Mass.	W. I., C. L.	2 to 20	855	0	35 17	5 55	[1] 1 00	10 5	0	120	2	327	130	22	. . . .
20	Providence, R. I.	{ Low Serv., C. I.	6 to 36	26 162	2 365	314 85	. .	. .	0	28	1 815	75	3 286	32	. .	64 to 73
		{ High Serv. Fire, C. I.	12, 16, 24	. .	. .	5 57	. .	. .	. .	2	91	. .	31	4	. .	114
21	Reading, Mass.	C. I.	4 to 12	3 139	0	23 61	0	0	0	4	125	5	212	0	14	68 to 78
22	Springfield, Mass.	{ W. I., W. I. C. L., / C. I. }	1 to 36	38 944	10 610	140 08	7 87	0 56	7 43	39	931	80	1 763	318	86	{ 100 to 120 / 30 to 35
23	Taunton, Mass.	C. I.	4 to 30	11 827	0	75 94	35 83	3	1 3	20	761	22	529	12	52	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	9 515	545	60 63	2 94	22	0 53	20	782	60	1 332	. .	37	9 to 107
25	Waltham, Mass.	C. I., W. I., C. L.	2 to 24	3 966	. .	50	4 23	[1] 0 5	. .	13	319	10	643	. .	. .	58
26	Wellesley, Mass.	C. I.	4 to 12	1 994	0	28 38	1 19	[1] 0 3	0 5	5	249	2	197	9	4	70
27	Whitman, Mass.	C. L., C. I.	. .	644	. .	16 5	. .	. .	. .	0	147	1	85	. .	. .	65
28	Woonsocket, R. I.	C. I.	4 to 20	7 323	. .	44 8	2 20	[1] 19 00	0	12	535	17	443	. .	16	50 to 120

[1] Per mile.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind.	Size. Inches.	Extended. Feet.	Discontinued. Feet.	Total in Use. Miles.	Added.	Total in Use.	Average Length of Services.	Average Cost of Services.	Added.	Now in Use. Domestic.	Now in Use. Manufacturing.	Added.	Total in Use.
1	Atlantic City, N. J.	C. I., L., G. I., T. L. G. I.	½ to 4	. .	. .	. .	. .	. .	. .	. .	501	2 636		.	. .
2	Attleboro, Mass.	. .	. .	. .	. .	. .	. .	. .	. .	. .	48	788		.	2
3	Billerica, Mass.	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
4	Boston, { Cochituate	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
	Mass. { Mystic	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
5	Brockton, Mass.	W. I., L. L., C. L., C. I.	¾ to 6	7 813	277	27 81	128	4 957	56 2	. .	222	3 923		.	. .
6	Burlington, Vt.	G. I., L.	½ to 6	1 800	60	17	67	3 202	27	$ 7 60	162	1 926	37	2	35
7	Concord, N. H.	. .	. .	1 665	. .	14 42	68	3 240	. .	. .	152	778		.	. .
8	Fall River, Mass.	Lead.	½ to 2	. .	. .	. .	154	6 576	. .	. .	174	6 128		.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	¾ to 8	4 456	. .	46 27	96	4 265	57	20	146	1 982	195	4	84
10	Holyoke, Mass.	C., R. L., Enam., C. I., L. L.	⅝ to 4	1 240	5	13 26	62	3 501	20	14 56	9	208		3	48
11	Keene, N. H.	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
12	Lowell, Mass.	. .	. .	6 534	. .	. .	165	. .	. .	. .	482	4 866		.	. .
13	Lynn, Mass.	I., C. L., Adam., G. I., L. L.	¾ to 10	5 446	820	93 3	98	11 452	. .	. .	206	2 074		.	. .
14	Middleboro, Mass.	W. I. C. L., L.	⅜ to 3	1 211	. .	8 5	22	769	55	. .	22	310		0	6
15	New Bedford, Mass.	L., C. I.	½ to 10	12 226	260	58 79	154	9 014	47	27 59	113	669	62	.	104
16	New London, Conn.	W. I. C. L., G., C. I., L.	½ to 4	1 490	0	10 6	81	2 892	19	10 76	11	208		1	17
17	Newton, Mass.	L., W. I., C. I.	½ to 6	13 200	4 100	75 5	198	6 771	58	22 50	329	5 429	25	0	17
18	Oberlin, Ohio	G. I., L.	¾ to 2	. .	. .	. .	30	565	25	8	46	253	5	0	0
19	Plymouth, Mass.	L., C. L.	½ to 1	420	. .	5 74	47	1 758	17 67	4 60	.	. .	.	0	1
20	Providence, R. I.	L., C. I.	½ to 10	. .	. .	. .	566	20 473	. .	. .	709	16 388		8	146
21	Reading, Mass.	G. I., C. L. I., L. L. I., C. I.	¾ to 6	2 567	0	11 67	41	928	62 60	31 41	665	851		0	3
22	Springfield, Mass.	W. I. (Tarred & Galv.), C. I.	½ to 6	. .	. .	. .	349	9 070	. .	. .	231	2 727		28	202
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	¾ to 3	6 917	6 054	40 98	146	4 233	. .	38 44	87	1 469	154	0	14
24	Troy, N. Y.	Lead, C. I.	¾ to 6	. .	. .	. .	264	7 309	35	25	23	292		.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	¾ to 10	7 271	148	36 8	55	3 192	130	107 82	0	72		0	6
26	Wellesley, Mass.	C. I., W. I. C. L., I.	½ to 6	2 324	. .	13 65	29	795	80	9 86	21	732	5	0	2
27	Whitman, Mass.	. .	. .	. .	. .	. .	22	925	. .	. .	.	425		.	. .
28	Woonsocket, R. I.	Lead, Iron.	⅝ to 6	1 028	. .	5 91	68	2 010	18 72	14 07	93	1 722	56	0	12

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1	2.—Description of Coal Used.					
						Builders of Pumping Machinery.	*b* Kind.	*c* Size.	*d* Brand.	*e* Price per Ton.	*f* Per Cent. of Ash.	*g* Wood. Price per Cord.
1	Atlantic City, N. J.											
2	Attleboro, Mass. . .	1873	Town.	Well near Seven Mile River.	Pumping to Standpipe.	Deane, Barr.	Bituminous.		Georges Creek.	$4 25		
3	Billerica, Mass. . . .	1898		Driven Wells.	Pumping to Mains and to Standpipe.	Barr.	Bituminous.		Georges Creek.			
4	Boston, Mass. . . .											
5	Brockton, Mass. . .	1880	City.	Storage Reservoirs.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt. . . .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Reynoldsville.	2 67½		
7	Concord, N. H. . . .											
8	Fall River, Mass. . .	1874	City.	Watuppa Lake.	Pumping to Standpipe and Tanks.	Worthington, Davidson.			Georges Creek.			
9	Fitchburg, Mass. . .	1873	City.	Storage Reservoirs.	Gravity.							
10	Holyoke, Mass. . . .											
11	Keene, N. H.	1868	City.	Sylvan and Echo Lakes.								
12	Lowell, Mass.	1870–96	City.	Driven Wells.	Pumping to Reservoir and Direct.	Morris, Worthington, Deane, Knowles.	Bituminous.	Broken.	Cumberland.	3 85		
13	Lynn, Mass.											
14	Middleboro, Mass. .	1885	F. Dist.	Well.	Pumping to Reservoir and Direct.	Deane.	Bituminous.		Georges Creek & Pocahontas.	3 85		

15	New Bedford, Mass.	1866–'99	City.	Little Quittacas Pond.	Pumping to Reservoir and Gravity.	McAlpine, Worthington, Leavitt,	Bituminous.		Pocahontas.	$3 50 3 75 4 00	7	$4 00
16	New London, Conn.	1872	City.	Lake Konomoc.								
17	Newton, Mass. . . .	1876	City.	Filter Basin fed by Springs and Driven Wells.	Pumping to Reservoir through Mains.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek.	4 50	8	6 00
18	Oberlin, Ohio	1887	Village.	East Branch Vermillion River.	Pumping.	Deane.	Bituminous.	Run of Mine.	Pocahontas.	3 36		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.	Various		5 00		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Worthington, Cornish, Corliss, Nagle and Holly.	Bituminous and Anthracite.	Egg.	Georges Creek & Reading.	3 98 5 04 5 17		4 50 5 00 5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 60		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond and Assowompsett Pond.	Gravity and Pumping.	Holly, Allis.	Bituminous.		Cumberland.	3 35 3 75	8.28 0.43	
24	Troy, N. Y.	1833–99	City.	Five Artificial Storage Reservoirs and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 57 2 40	17.24	5 00
25	Waltham, Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Barr, Worthington.	Bituminous.		Georges Creek.	3 90	10	
26	Wellesley, Mass. . .	1884	Town.	Wells.	Pumping to Reservoir.	Blake.	Bituminous.		Georges Creek, Puritan.	4 00	9.3	3 50
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Deane, Worthington.	Bituminous.		Georges Creek.	4 08	6.5	3 00

1899.—TABLE I., *Continued.*—GENERAL AND PUMPING.

Number.	3	4	5	6	7	8	9	10	11	12	13	14
	Coal Consumed for the Year. Lbs.	Lbs. of Wood ÷ 3.	Total Fuel Consumed for the Year. Lbs.	Total Pumpage for the Year in Gallons.	Average Static Head against which Pumps Work. Feet.	Average Dynamic Head against which Pumps Work. Feet.	Number of Gallons per Pound of Coal.	Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
2	547 821	1 000	548 821	133 157 440	160	188	244	38 300 000	$22 15	$0 118	$168 70	$0 898
3	215 787	. .	. . .	14 727 118	. .	. . .	172	17 519 482	. . .	. . .	. . .	. . .
4	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
5	413 808	. .	. . .	415 075 817	. .	43	1 002 91	. . .	. . .	. . .	. . .	. . .
6	. . .	. .	. . .	308 912 525	289	316	. .	. . .	19 91	0 06	119 92	0 379
7	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
8	3 991 080	. .	. . .	1 307 026 763	. .	185 7	327 37	. . .	9 43	. . .	107 38	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	10 173 433	2 400	. . .	2 659 052 210	156 22	163 07	266	68 621 177	8 41	0 0516	. . .	. . .
13	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
14	528 450	. .	528 450	81 811 000	182	203	154 62	26 189 036	29 73	0 1465	81 82	0 403
15	1 281 100 310 350 476 800	75 75 0	1 281 175 310 425 476 800	887 751 910 148 573 352 369 980 892	124 9 127 79 125 1	134 16 129 29 127 41	693 479 776	77 530 442 51 607 785 82 454 168	. . .	. . .	. . .	. . .
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	5 49	0 0416	. . .	. . .
17	2 219 000	6 000	2 225 000	743 282 000	234	254	334	70 700 000	12 59	0 049	155 02	0 61
18	360 000	. .	. . .	38 759 000	80	80	108	7 183 000	38 00	0 47	136 00	1 70
19	271 354	14 000	285 354	117 664 272	65	66	433 61	23 867 628	14 76	0 22	102 70	1 60
20	5 395 900 43 014 788 971	300 40 1 017	5 396 200 43 054 789 988	3 692 751 000 22 749 951 504 259 180	170 39 110 08 111 96	176 46 117 23 126 42	684 529 639	100 710 400 51 662 100 67 326 600	4 27 14 90	0 0242 0 1085	. . .	. . .
21	392 661	. .	392 661	47 971 992	219	240	122	. . .	51 53	0 2147	292 80	1 22
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	830 100	. .	830 100	526 759 797	. .	61 65	635 17	32 627 315	9 84	0 1596	96 97	1 57
24	12 477 895	. .	. . .	2 787 764 573	231	242	223 42	45 091 656	11 71	0 0484	. . .	. . .
25	1 376 005	. .	. . .	739 981 774	164	180	270 671	82 377 990	13 15	0 073	53 70	0 30
26	456 102	98	456 200	77 456 293	250	278	169	39 368 701	24 68	0 089	221 92	0 798
27	. . .	. .	. . .	59 058 124	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	1 101 150	251	1 101 401	292 314 210	238	239	. .	52 915 497	12 75	0 053	104 25	0 43

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates. Domestic.	Rates. Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	. . .	. . .	$ 19 968 89	. . .	. . .
3	Billerica, Mass.	$ [1] 829 73	$ [2] 1 182 29	2 012 02	$ 128 87	$ 2 140 89
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] 58 046 16	[2] 8 135 02	66 181 18	7 096 66	73 277 84
6	Burlington, Vt.	39 068 93	3 334 66	42 403 59	1 533 36	43 936 95
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 148 285 71	[2] 4 620 73	152 906 44	7 455 63	160 362 07
9	Fitchburg, Mass.	[1] 39 974 93	[2] 23 343 70	. . .	. . .	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	21 827 37
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	. . .	. . .	. . .	. . .	. . .
14	Middleboro, Mass.	[1] 6 736 09	[2] 3 986 27	10 722 36	201 77	10 924 13
15	New Bedford, Mass.	90 243 26	8 882 01	99 125 27	61 00	99 186 27
16	New London, Conn.	. . .	. . .	. . .	. . .	45 021 70
17	Newton, Mass.	[1] 102 819 70	[2] 18 735 79	121 546 49	9 385 41	130 931 90
18	Oberlin, Ohio	4 901 78	244 00	5 145 78	515 88	5 661 66
19	Plymouth, Mass.	19 293 33	1 343 86	20 637 19	241 86	20 879 05
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	7 570 41	137 61	7 708 02	271 02	7 979 04
22	Springfield, Mass.	[1] 63 314 94	[2] 144 367 18	207 682 12	21 988 76	229 670 88
23	Taunton, Mass.	41 655 47	11 666 12	53 321 59	520 63	53 842 22
24	Troy, N. Y.	[1] 21 910 11	[2] 75 412 87	97 322 98	7 366 84	104 689 82
25	Waltham, Mass.	56 804 95	6 965 94	63 770 89	2 140 19	65 911 08
26	Wellesley, Mass.	12 677 91	231 59	12 909 50	357 71	13 267 21
27	Whitman, Mass.	4 229 95	2 803 98	7 033 93	662 44	7 696 37
28	Woonsocket, R. I.	36 461 47	7 842 35	44 303 82	99 96	44 403 78

[1] Meter Rates. [2] Faucet or Schedule Rates.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J	Total from Public Funds.	K	AA	BB	CC	DD	EE
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.		Gross Receipts.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	. . .	$ 7 116 04	$ 7 116 04	$ 27 084 93	$ 9 847 19	$ 12 582 50	$ 22 429 69	[2] $ 4 650 00 5 24	$ 27 084 93
3	$ 2 300 00	. . .	. . .	. . .	1 000 00	3 300 00	5 440 89	1 504 69	3 600 00	5 104 69	336 20	5 440 89
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	77 277 84	13 322 10	31 675 00	44 997 10	[2] 32 280 74	77 277 84
6	3 480 00	$ 250 00	2 357 15	$ 291 97	. . .	6 379 12	50 316 07	26 856 67	10 080 00	36 936 67	[3] 2 726 42 [2] 7 829 11 2 823 87	50 316 07
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	. . .	. . .	46 568 99	104 870 00	151 438 99	. . .	. . .
9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
11	5 350 00	150 00	1 000 00	175 00	. . .	6 675 00	28 502 37	2 393 61	4 845 00	7 238 61	21 263 76	28 502 37
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
14	. . .	. . .	. . .	. . .	1 700 00	1 700 00	12 624 13	4 233 83	2 460 00	6 693 83	[2] 3 000 00 [3] 528 25	. . .
15	. . .	. . .	. . .	. . .	75 800 00	[1] 14 714 76 [1] 75 800 00	179 701 03	54 101 03	78 800 00	132 901 03	[2] 26 800 00 [4] 20 000 00	179 701 03
16	9 720 00	150 00	3 600 00	300 00	. . .	13 770 00	58 791 70	6 480 51	24 540 00	31 020 51	[3] 27 771 19	58 791 70
17	. . .	. . .	. . .	. . .	. . .	. . .	130 931 90	17 253 30	97 500 00	114 753 30	16 178 60	130 931 90
18	. . .	. . .	. . .	. . .	3 963 78	3 963 78	9 625 44	3 130 22	2 139 54	5 269 76	[3] 2 070 92 [2] 2 284 76 [4] 5 140 00 [3] 99 72	9 625 44
19	. . .	. . .	. . .	. . .	. . .	. . .	20 879 05	12 190 53	3 448 80	15 639 33		20 879 05
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	3 750 00	300 00	. . .	. . .	2 410 00	6 460 00	14 439 04	5 507 44	8 540 00	14 047 44	391 60	14 439 04
22	19 060 00	1 680 00	5 379 12	8 095 30	. . .	34 214 42	263 885 30	22 667 04	90 750 00	113 417 04	. . .	. . .
23	2 000 00	2 499 82	800 00	454 44	4 424 90	10 179 16	64 021 38	21 471 35	29 608 00	51 079 35	[2] 12 942 03	64 021 38
24	. . .	. . .	. . .	. . .	. . .	. . .	104 689 82	62 735 27	9 360 00	72 095 27	[2] 19 825 00 [3] 12 769 55	104 689 82
25	. . .	. . .	. . .	. . .	. . .	. . .	65 911 08	23 494 53	16 240 00	39 734 53	[2] 23 216 62 2 959 93	65 911 08
26	4 560 00	400 00	200 00	116 86	596 80	5 873 66	19 140 87	5 527 74	10 940 00	16 467 74	. . .	. . .
27	2 560 00	. . .	. . .	. . .	. . .	2 560 00	10 256 37	4 286 08	4 000 00	8 286 08	[3] 1 970 29	10 256 37
28	15 812 50	1 646 44	1 914 73	1 119 42	12 000 00	32 493 09	76 896 87	12 372 30	18 101 53	30 473 83	46 423 04	76 896 87

[1] From Maintenance. [2] To Sinking Fund. [3] To Construction. [4] Bonds paid.

1899.— TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Name of City or Town.	Receipts.				
		R	S	T	U	V
		Balance from Previous Year.	Bonds Issued.	Appropriations from Tax Levy.	Other Sources.	Total.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	$ 5 785 09	$16 111 95	. . .	$ 23 00	$21 920 04
3	Billerica, Mass.	16 302 09	. . .	. . .	1 774 28	18 076 37
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	9 622 11	22 000 00	. . .	3 026 75	34 648 86
6	Burlington, Vt.	[1] 2 726 42	. . .	. . .	. . .	2 726 42
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	. . .	. . .	$ 6 200 00	2 169 39	8 369 39
9	Fitchburg, Mass.	. . .	. . .	. . .	. . .	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	. . .	. . .	. . .	. . .	. . .
14	Middleboro, Mass.	[1] 528 25	. . .	. . .	762 22	1 290 47
15	New Bedford, Mass.	35 840 11	. . .	. . .	6 585 60	42 425 71
16	New London, Conn.	[1] 27 771 19 37 655 82	. . .	. . .	. . .	65 427 01
17	Newton, Mass.	. . .	18 336 44	. . .	11 035 51	29 371 95
18	Oberlin, Ohio	. . .	. . .	. . .	2 524 68	2 524 68
19	Plymouth, Mass.	[1] 2 749 38 [1] 99 72	. . .	. . .	2 126 27	4 975 37
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	55 28	9 027 90	. . .	987 54	10 070 72
22	Springfield, Mass.	392 27 [1] 32 095 97	. . .	. . .	. . .	32 488 24
23	Taunton, Mass.	986 05	30 000 00	. . .	4 900 53	35 886 58
24	Troy, N. Y.	[1] 12 769 55 9 565 85	. . .	. . .	. . .	22 335 40
25	Waltham, Mass.	6 817 98	. . .	. . .	2 329 66	9 147 64
26	Wellesley, Mass.	1 894 31	4 000 00	. . .	1 591 73	7 486 04
27	Whitman, Mass.	[1] 1 970 29 2 234 60	. . .	. . .	5 50	4 210 39
28	Woonsocket, R. I.	. . .	. . .	10 013 39	2 561 70	12 575 09

[1] From Maintenance Account.

Number.	Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total for Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt to Date.	Value of Sinking Fund to Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	$ 5 031 21	$1 618 71	$ 6 153 86	$12 803 78	$ 9 116 26	$21 920 04	$ 348 331 25	$ 293 000 00	$ 54 666 06	. . .
3	. . .	. . .	. . .	17 391 66	684 71	18 076 37	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	19 159 73	. . .	6 807 12	25 966 85	8 682 01	34 648 86	890 462 30	792 000 00	301 000 00	4
6	2 191 04	535 38	. . .	2 726 42	. . .	2 726 42	465 839 73	248 000 00	196 359 82	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	7 169 39	. . .	1 193 84	8 363 23	6 16	8 369 39	. . .	2 000 000 00	628 968 56	5.2
9	. . .	. . .	. . .	. . .	. . .	. . .	463 193 84	636 000 00	172 806 16	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	312 934 31	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
14	492 24	798 23	. . .	1 290 47	. . .	1 290 47	113 812 12	59 500 00	5 173 39	4
15	16 904 98	7 969 05	. . .	24 874 03	[1] 4 714 76 12 836 92	42 425 71	1 800 301 78	540 000 00	121 263 77	4.48
16	13 848 74	1 412 02	9 570 30	24 831 06	40 595 95	65 427 01	691 866 18	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	29 371 95	. . .	29 371 95	2 072 587 67	2 075 000 00	787 860 98	4.7
18	795 02	1 096 23	135 69	2 026 94	497 74	2 524 68	83 880 21	49 000 00	1 284 76	3.5 & 5.75
19	1 669 53	455 90	2 849 94	4 975 37	. . .	4 975 37	266 898 78	82 600 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	4 180 62	3 348 52	1 700 00	9 229 14	841 58	10 070 72	252 372 73	216 000 00	. . .	4
22	10 069 22	. . .	22 026 75	32 095 97	392 27	32 488 24	2 115 576 49	1 525 000 00	378 823 07	5.89
23	8 364 16	6 094 91	14 457 31	28 916 38	6 970 20	35 886 58	1 219 558 80	755 200 00	136 807 66	4
24	6 924 89	. . .	. . .	6 924 89	15 410 51	22 335 40	1 300 019 40	236 000 00	54 112 50	4
25	. . .	. . .	. . .	8 935 06	212 58	9 147 64	. . .	406 000 00	74 190 31	4
26	3 260 34	1 149 08	2 531 47	6 940 89	545 15	7 486 04	311 456 22	269 000 00	73 007 80	4
27	. . .	. . .	. . .	1 392 81	2 817 58	4 210 39	127 281 85	100 000 00	31 281 10	4
28	. . .	. . .	. . .	10 013 39	. . .	. . .	428 128 53	. . .	. . .	. . .

[1] To Maintenance Account.

Number.	Name of City or Town.	1	2	3	4	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.			Total Gallons Consumed for the Year.	Quantity Used through Domestic Meters. Gallons.	Quantity Used through Manufacturing Meters. Gallons.		Average Daily Consumption. Gallons.	Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at Date.						Each Inhabitant.	Each Consumer.	Each Tap.
1	Atlantic City, N. J.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
2	Attleboro, Mass.	9 500	8 000	7 500	133 157 440	. . .	. . .	. .	364 638	38 4	46 8	. .
3	Billerica, Mass.	2 600	1 800	1 162	. . .	. . .	. . .	. .	40 183	. .	34 5	. .
4	Boston, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
5	Brockton, Mass.	38 000	36 000	34 000	415 075 817	155 038 125	50 432 925	. .	1 137 194	29 15	33 44	220 68
6	Burlington, Vt.	18 600	18 100	17 900	308 912 525	135 874 125	17 165 250	50	846 335	46	47	257
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
8	Fall River, Mass.	102 281	. .	98 931	1 307 026 763	. . .	. . .	. .	3 580 895	35 01	36 2	. .
9	Fitchburg, Mass.	29 000	23 000	. .	940 000 000	. . .	. . .	. .	2 600 000	. .	113	. .
10	Holyoke, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
11	Keene, N. H.	8 000	7 500	7 400	547 500 000	. . .	. . .	. .	1 500 000	188	203	884
12	Lowell, Mass.	. . .	. .	. .	2 659 464 909	. . .	. . .	. .	7 286 205	. .	81	. .
13	Lynn, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
14	Middleboro, Mass.	Town 7 000 / F.Dist. 4 200	4 000	3 750	81 811 000	13 955 460	25 195 303	. .	224 140	53 37	59 75	282
15	New Bedford, Mass.	58 000	51 000	50 000	2 261 115 500	98 682 480	332 112 000	18 1	6 194 837	107	124	677
16	New London, Conn.	16 500	15 800	15 300	526 679 171	. . .	. . .	. .	1 442 957	87 5	94 3	482 6
17	Newton, Mass.	30 000	29 600	29 400	743 274 700	340 000 000	34 000 000	. .	2 036 369	67 9	68 8	293
18	Oberlin, Ohio	4 800	3 600	2 800	38 759 000	11 639 000	1 220 000	33	106 000	22	38	178
19	Plymouth, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
20	Providence, R. I.	178 900	. .	. .	3 490 151 148	. . .	. . .	. .	9 562 058	53	. .	455
21	Reading, Mass.	4 850	4 300	4 010	47 971 992	. . .	. . .	. .	131 430	27 09	32 74	129 1
22	Springfield, Mass.	61 238	52 000	47 000	1 937 055 000	386 690 461		20	5 307 000	87	113	561
23	Taunton, Mass.	27 093	27 000	26 890	526 759 797	82 510 469	127 498 712	. .	1 443 177	53	53 7	330
24	Troy, N. Y.	65 000	61 000	58 000	3 439 764 573	406 125 475		. .	11 241 061	173	194	1 516
25	Waltham, Mass.	23 500	22 900	22 600	739 981 774	36 229 102		. .	2 027 178	86	89	620
26	Wellesley, Mass.	4 400	4 341	4 191	77 456 293	45 598 093	225 680	. .	212 209	48	51	255
27	Whitman, Mass.	. . .	. .	. .	59 058 124	. . .	. . .	. .	161 803	. . .	. . .	65
28	Woonsocket, R. I.	28 500	26 500	26 000	292 241 976	. . .	. . .	. .	800 922	22	28	380

1899.—TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Pipe. Inches.	3 Length Extended During the Year in Feet.	4 Length Discontinued During the Year in Feet.	5 Total Length in Use. Miles.	6 Cost of Repairs per Mile.	7 Number of Leaks for Year.	8 Length of Pipe Less than 4 In. Diam. Miles.	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number Blow-off Gates.	15 Range of Pressure on Mains at Center for Day and Night. Pounds.
1	Atlantic City, N. J.															
2	Attleboro, Mass.	W. I., C. I., C. L.	1 to 16	1 845		30 63		11		6	251					54 to 62
3	Billerica, Mass.	C. I.	6 to 12			9 4		3			94		83			54 to 120
4	Boston, Mass. { Cochituate / Mystic															
5	Brockton, Mass.	W. I., C. L., C. I.	6 to 30	8 434		64 09	$ 3 53	[1] 0 61		16	592	29	747		21	47 to 56
6	Burlington, Vt.	C. L., C. I., W. I.	4 to 30	2 596	4 360	38 0	10 19	[1] 0 36	2 7	8	213	33	606	59	12	70 to 85
7	Concord, N. H.															
8	Fall River, Mass.	C. I.	6 to 24			85 95				22	934	19	924			80
9	Fitchburg, Mass.	C. I.	2 to 30	10 053		65 62				29	476	14	542			75 to 155
10	Holyoke, Mass.															
11	Keene, N. H.	W. I., C. L., C. I.	4 to 24	3 140	0	35 18	4 60	[1] 0 5	3 25	3	214	5	357		27	40 to 60
12	Lowell, Mass.			7 847		126 41					1 155		1 166			
13	Lynn, Mass.															
14	Middleboro, Mass.	C. I.	4 to 12	373		16 25		0		0	114	3	161		5	45 to 60
15	New Bedford, Mass.	C. I.	4 to 36	8 225	1 580	90 6	27 29	22	1 18	10	723	15	1 027	79	93	28 to 64
16	New London, Conn.	W. I., C. L., C. I.	4 to 24	14 384	0	48 8	9 73	24	3 0	15	243	30	304		30	40 to 48
17	Newton, Mass.	C. I.	4 to 20	9 430	200	135 4	8 00	4	2 9	26	930	17	790	47	368	84
18	Oberlin, Ohio	C. I.	4 to 12	2 324	0		0	0	0 33	4	87	3	56	2	2	27 to 32
19	Plymouth, Mass.	W. I. C. L., W. I.	2 to 20	4 788	0	38	12 93	2	10 5	0	130	7	334	133	22	
20	Providence, R. I.	C. I. (high pres're.)	12, 16, 24	19 645	769	5 57			0	1	92	46	31		4	114
		C. I.	6 to 36			318 43				39	1 854		3 331		32	64 to 73
21	Reading, Mass.	C. I.	4 to 12	4 414	0	24 61	0	0	0	6	131	8	220	0	14	68 to 78
22	Springfield, Mass.	W. I., W. I. C. L., C. I.	1 to 36	23 369	6 833	143 21	8 46	45	7 3	22	953	74	1 837	334	89	30 to 120
23	Taunton, Mass.	C. I.	4 to 30	6 072	0	77 09	26 74	10	1 85	11	771	14	540	12	54	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	4 827	965	61 36	1 86	17	0 53	1	783	16	1 348	0	38	9 to 107
25	Waltham, Mass.	C. I., W. I., C. L.	2 to 24	548		50	4 20	[1] 0 5		6	325	7	650			58
26	Wellesley, Mass.	C. I.	4 to 12	3 336	0	29	0 78	[1] 0 2	0 50	8	257	5	202	9	4	70
27	Whitman, Mass.	C. L., C. I.		1 020		16 7				1	148	1	86			
28	Woonsocket, R. I.	C. I.	4 to 20	2 607		45 32	17 23	[1] 44	0	5	540	5	448		15	50 to 120

[1] Per mile.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind.	Size. Inches.	Extended. Feet.	Discontinued. Feet.	Total in Use. Miles.	Added.	Total in Use.	Average Length of Services. Feet.	Average Cost of Services.	Added.	Now in Use. Domestic.	Now in Use. Manufacturing.	Added.	Total in Use.
1	Atlantic City, N. J.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	64	852	.	.	2
3	Billerica, Mass.	C. L. W. I.	. .	3 705	. .	2 14	51	187	. .	. .	15	54	.	.	. .
4	Boston, Mass. { Cochituate / Mystic	. . .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
5	Brockton, Mass.	W. I., L. L., C. I.	¾ to 6	11 462	244	29 93	183	5 140	60 64	. .	213	4 136	.	.	. .
6	Burlington, Vt.	G. I., C. I., Lead.	½ to 6	2 717	224	17 4	90	3 292	28	$8 8 80	158	2 082 39	0		35
7	Concord, N. H.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
8	Fall River, Mass.	Lead.	½ to 2	. .	. .	. .	207	6 783	. .	. .	235	6 363	.	.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	¾ to 8	. .	. .	. .	94	4 359	. .	. .	127	2 304	5		89
10	Holyoke, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
11	Keene, N. H.	W. I., C. L., G., Lead.	¾ to 6	1 100	0	9 64	44	1 697	. .	. .	7	94	1		10
12	Lowell, Mass.	. . .	. .	. .	. .	78 3	167	10 529	. .	. .	413	5 268	.	.	. .
13	Lynn, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	.	. .	.	.	. .
14	Middleboro, Mass.	W. I. C. L., Lead.	¾ to 3	2 638	. .	9 0	26	794	101 5	. .	23	332	1		7
15	New Bedford, Mass.	Lead, C. I.	½ to 10	6 389	389	59 93	144	9 151	44	24 82	364	1 035 59	.		99
16	New London, Conn.	W. I., C. L., G., C. I., Lead.	½ to 4	1 643	101	10 9	99	2 991	15 6	11 19	17	225	0		17
17	Newton, Mass.	Lead, W. I., C. I.	½ to 6	17 500	5 500	77 8	174	6 945	59	22 60	368	5 747 25	0		17
18	Oberlin, Ohio	G. I., Lead.	¾ to 2	. .	. .	. .	31	596	25	8 00	47	300 5	0		0
19	Plymouth, Mass.	Lead, C. L.	½ to 1	817	. .	5 85	77	1 832	17	5 92	.	. .	0		1
20	Providence, R. I.	Lead, C. I.	½ to 10	. .	. .	. .	606	21 020	. .	. .	376	17 124	8		154
21	Reading, Mass.	G. I., C. L., I., L. L. I., C. I.	¾ to 6	9 850	293	13 43	90	1 018	106 16	37 20	66	917	0		2
22	Springfield, Mass.	W. I. (Tarred & Galv.), C. I.	½ to 6	. .	. .	. .	386	9 456	. .	. .	171	2 898	24		226
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	¾ to 3	7 106	6 179	42 33	155	4 372	. .	26 51	110	1 572 161	2		16
24	Troy, N. Y.	Lead, C. I.	¾ to 6	. .	. .	. .	104	7 413	35	25 00	21	309	.	.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	¾ to 10	6 074	403	38	71	3 225	85	24 98	6	78	0		6
26	Wellesley, Mass.	C. I., W. I. C. L., I.	½ to 6	4 568	. .	14 5	41	836	114	14 99	30	763 5	0		2
27	Whitman, Mass.	. . .	. .	. .	. .	. .	40	965	. .	. .	.	450	.	.	. .
28	Woonsocket, R. I.	Lead, Iron.	⅝ to 6	1 305	0	6 16	98	2 108	13 29	12 48	60	1 777 61	0		12

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THE "AA" EMPIRE WATER METER

IS STEADILY GAINING.

A thorough test will fully prove all we claim for the "AA" EMPIRE METER

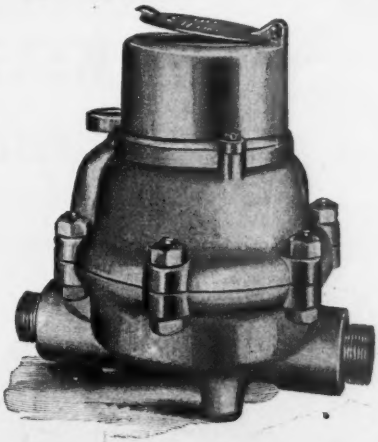
265,000

CROWN—EMPIRE—NASH—GEM METERS IN USE

NATIONAL METER COMPANY,

84 AND 86 CHAMBERS STREET, NEW YORK.

318 DEARBORN STREET, CHICAGO. 159 FRANKLIN STREET, BOSTON. SARACON CHAMBERS, LONDON.



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HERSEY ROTARY METER

HERSEY TORRENT METER

The above are trade names given to the WATER METERS of our manufacture.

A full description of each type can be found in our illustrated catalog, which we would be glad to supply you if you are interested.

Over 14 years' experience in the manufacture of WATER METERS.

Over 1000 cities and towns using our meters.

HERSEY MANUFACTURING CO.

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NEW ENGLAND OFFICE, TREMONT TEMPLE, BOSTON.

NEW YORK, 278 Pearl Street. CHICAGO, 224 Lake Street.

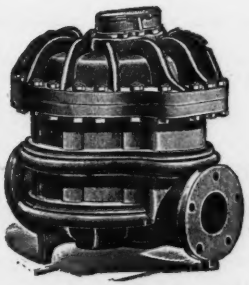
LAMBERT METER

METER No. 50,000	STAMPED AND SHIPPED TO COUNCIL BLUFFS, IOWA, MARCH 31, 1894.
METER No. 100,000	STAMPED AND SHIPPED TO PROVIDENCE, RHODE ISLAND, AUGUST 24, 1897.
METER No. 150,000	STAMPED AND SHIPPED TO WOONSOCKET, R. I., DECEMBER 28, 1899.
METER No. 163,380	SOLD JULY 1, 1900.

UNION WATER METER CO.,

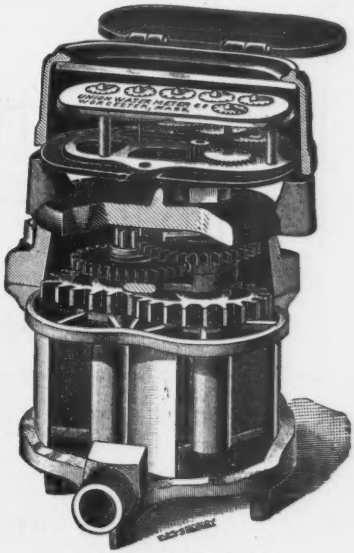
WORCESTER, MASS.

Incorporated 1868.



Extra Heavy Rotary Piston Meter.

Sectional Cut



Showing 58-inch Union Rotary Piston Meter.

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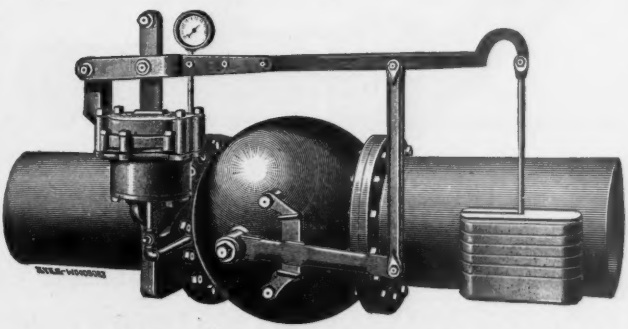
Sizes 4 inches to 16 inches.



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Water Pressure Regulator.

The only positive Automatic Water Pressure Regulator in the market. We have never had a failure.

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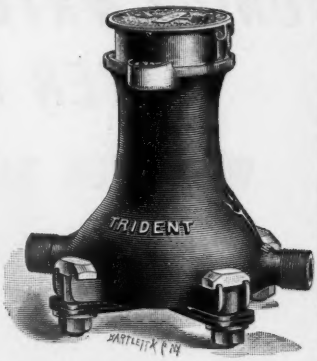
THE TRIDENT DISK WATER METER



WITH RESILIENT, RETROACTIVE, FROST BOTTOM.

MAY BE FROZEN SOLID

any number of times, without any damage to the meter and without any expense or annoyance to the owner.

SUPERIOR TO ALL

in convenience, in solidity of parts, in design, in maintained accuracy, and in immunity from stoppages.

MAY BE RUN HARD AND LONG

without smashing.

FULLY ATTESTED

by most competent authorities, as being "beyond competition in low cost of maintenance."

ILLUSTRATED CATALOGUE,

giving all details, free to any applicant.

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Water Meters will adjust bills and settle disputed contracts without further trouble.

Try them.

Pittsburg Meter Co., East Pittsburg, Pa.

D. M. J. S.

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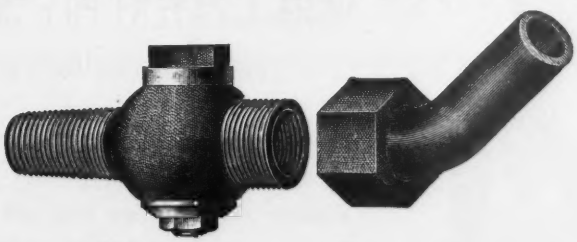

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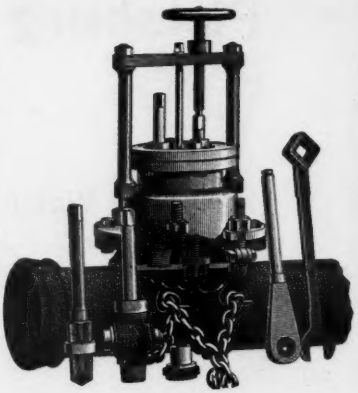

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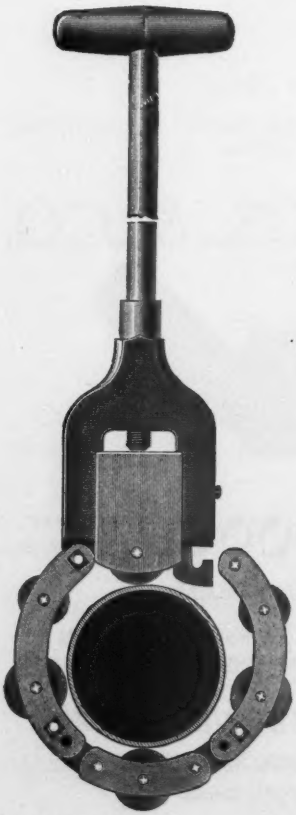

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Without an equal.
Three machines in one.
Endorsed by all who have used it.

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For Cutting Cast Iron Pipe in the Trench.

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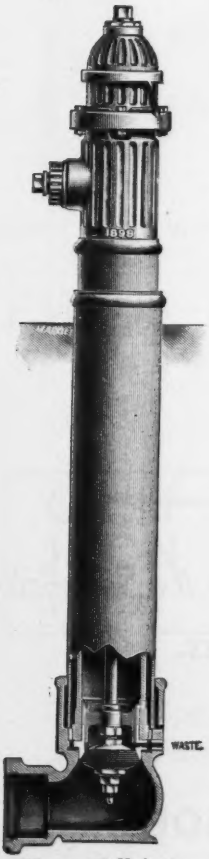

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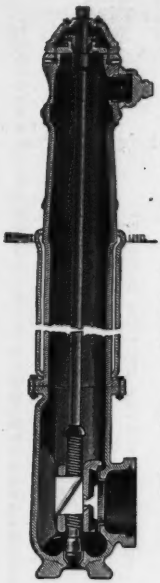

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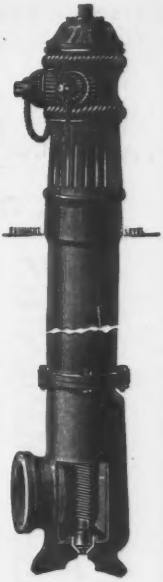

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HEAVY CASTINGS and those made from ORIGINAL DESIGNS.

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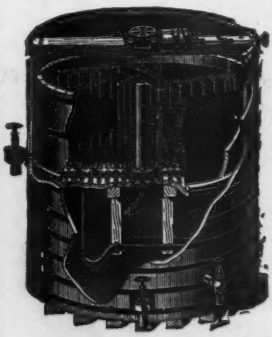

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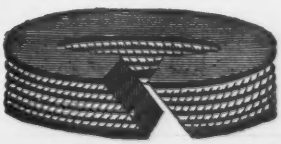
In ordering be careful to give the EXACT diameter of stuffing-box and of piston-rod or valve-stem.



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The New England Water Works Association

was organized in Boston, Mass., on June 21st, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until it now includes the names of over **500** men. Its membership is divided into two principal classes, viz.: ACTIVE and ASSOCIATE. The Active membership is further divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter THREE dollars. The annual dues for both classes of Active membership are TWO dollars. The Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues TEN dollars. This Association has four regular meetings each year, also a series of informal monthly meetings, during the winter months, at Boston, Mass.

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The Secretary would be pleased to give further information to any one desiring the same. Address,

WILLARD KENT,
Secretary New England Water Works Association,
Narragansett Pier, R. I.

DEC 1900

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